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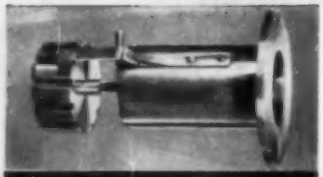
DECEMBER 1958



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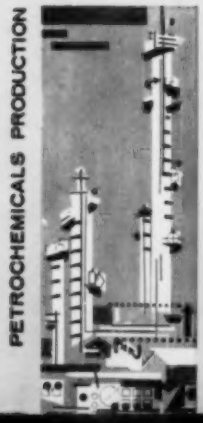

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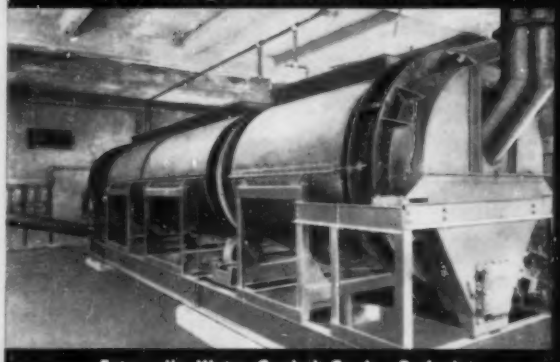

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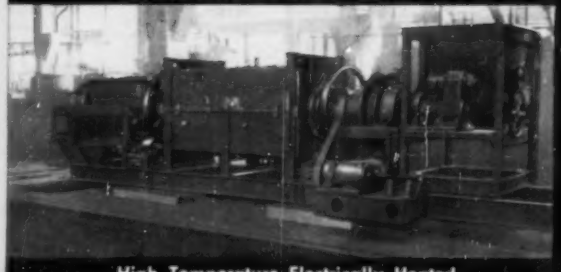

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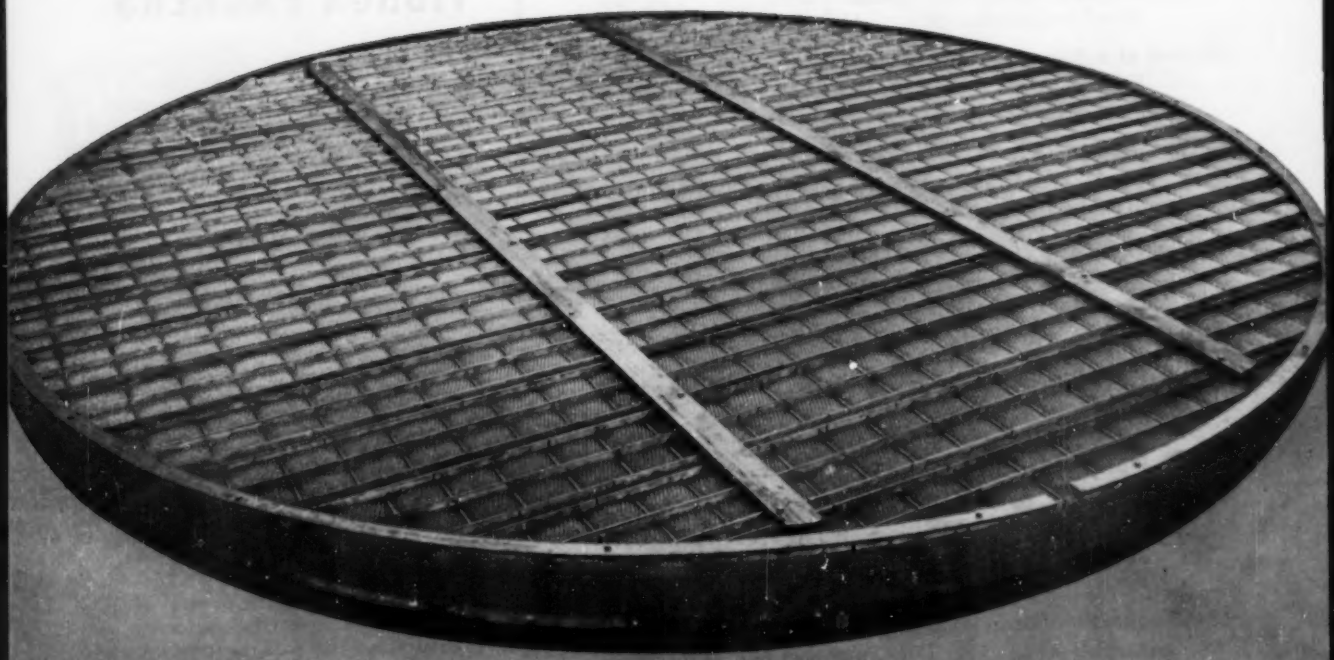

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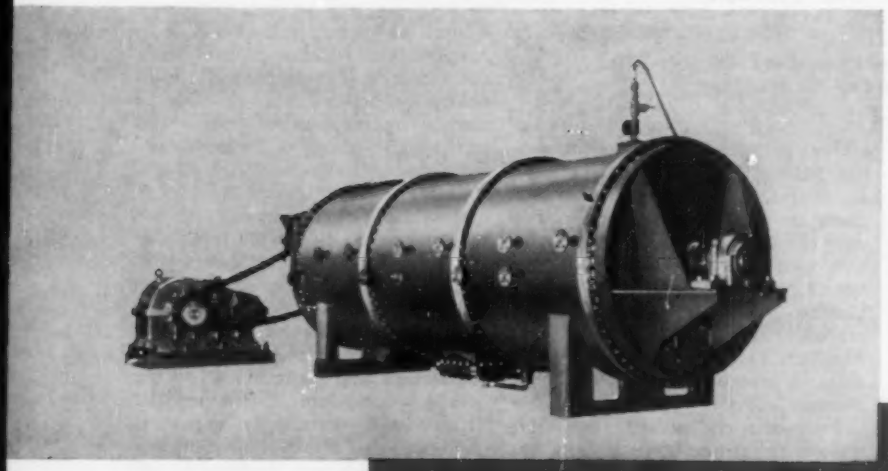
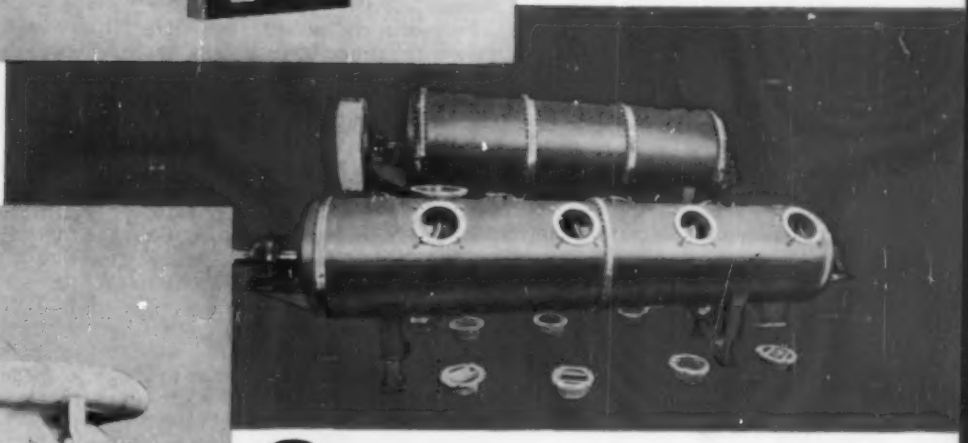
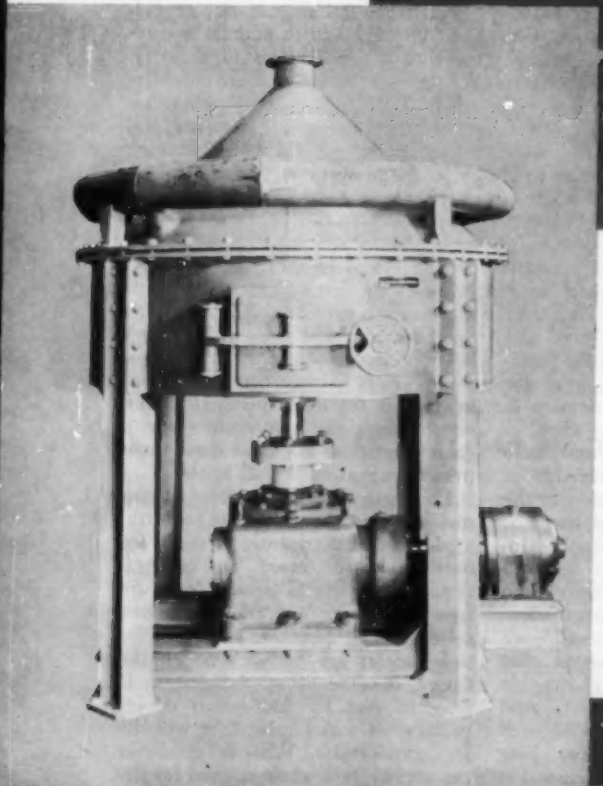


1. BATCH DRYERS—5' dia. x 16' long Bethlehem THERMOCOIL (Coil cast in wall) Batch Dryer. Material processed passes thru three stages: The feed material is in "soupy" form; as it dries it becomes a plastic mass; finally it turns to a powder. This three-purpose dryer is an excellent example of how Bethlehem's background of engineering helps manufacturers cut their equipment costs.





2. CONTINUOUS DRYER—In foreground, being assembled is 44" diameter 19' long Continuous Horizontal Dryer. Fabricated steel construction utilizing Hastalloy plow type agitators (seen through ports) 40 HP drive. This dryer is used to dry salt, evolving organic vapor product, on a continuous basis. Heat is provided through jacketed body. (In background is a Thermocoil dryer representing a repeat order of the batch dryer described under 1.)

3. PAN BATCH DRYER—5' 2" diameter Bethlehem Pan Dryer of stainless steel construction with scraped and jacketed flat bottom. Agitator provides plowing action to break up and circulate material. Agitation also provides for self-discharge through quick opening discharge door. Used to dry certain naval store products, rare metals and other materials handled more economically in a small scale batch operation.

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Science, Humanities and the Nation

MONROE E. SPAGHT
Executive Vice President, Shell Oil Company

. . . *The New York Times* made this point not long ago in an editorial titled "Science and Congress."

"Obviously we cannot expect each Congressman to be a mathematical physicist or a research chemist, but we have a right to expect that Congressmen voting on the appropriation of large sums for scientific research or for the large scale application of this research have enough basic background so they can understand testimony made before them and vote intelligently. It would seem wise if Congress itself, whose members must feel most keenly their deficiency in this area, took steps to improve the situation, since the need for scientific sophistication in Congress is likely to increase rather than decrease in the years ahead."

Scientific sophistication. The dictionary says if you are sophisticated you are worldly-wise. The good grey Times is telling Congress to get wise to the world of science.

It is no longer enough for governors to understand the art of government. They must also understand the great new force of science that will come increasingly to bear on all governments and all men for as many years as the mind can imagine.

The Times editorial is more than a plea for science-for-all. It is a shot fired at the ramparts that have traditionally stood between the intellectual disciplines, such as the wall that has given so many charming men of letters their excuse for remaining innocent of any mathematics beyond the process of balancing a check book or of any chemistry more complex than making martinis.

[On the other hand the scientist is often equally unsophisticated outside science.] I should like to offer for your consideration an idea—undoubtedly not new—aimed at broadening the scientists' point of view and enabling him to realize more fully his potential as a scientist and as a citizen.

The outstanding man of the first half of this century—and by that I mean the man who has been right most often on the most important questions—is generally agreed to have been Winston Churchill, statesman, soldier, journalist, former naval person, painter, bricklayer, but perhaps above all a great historian with a fine grasp of causes and effects in the story of mankind. Think of others who have seemed to understand their own age and to see it as a product of ages that had gone before and you would probably include Woodrow Wilson, Abraham Lincoln ("My fellow citizens, we cannot escape history.") and Thomas Jefferson.

From the rise of man until this minute, the nature of protoplasm has not changed very much, and neither have the basic needs and aspirations that drive men to act. The people who have the best understanding of what these needs and aspirations have been —the people who have a sense of history—are those best equipped to make intelligent predictions about the future behavior of man.

The great creative civilizations have risen among people who enjoyed relatively great freedom for their time, who valued education, and who nourished a sense of the past as well as an interest in the future. The great statesmen who have led nations through the nobler passages of history have understood these things. In ancient Greece, which appeared as a brilliant island in a dark barbarian sea, this breadth of knowledge and interest reached far through the population. The Greeks had a word for a person who did not participate in public affairs. The word was *idiot*.

Alongside history, we should also have a good working knowledge of our language and literature—not the sketchy, imperfect acquaintance that leaves so many of our people (including many with college degrees) unsure of themselves with certain pronouns and marks of punctuation. There should be an easy confidence about the use of the tongue that insures precision and clarity in thought and communication. And there should be some knowledge of great books. No man lives long enough to gain by experience the wisdom lying already distilled in the pages of a few classics. *Macbeth* tells more about ambition than you could learn from a wheelbarrow full of books on political science.

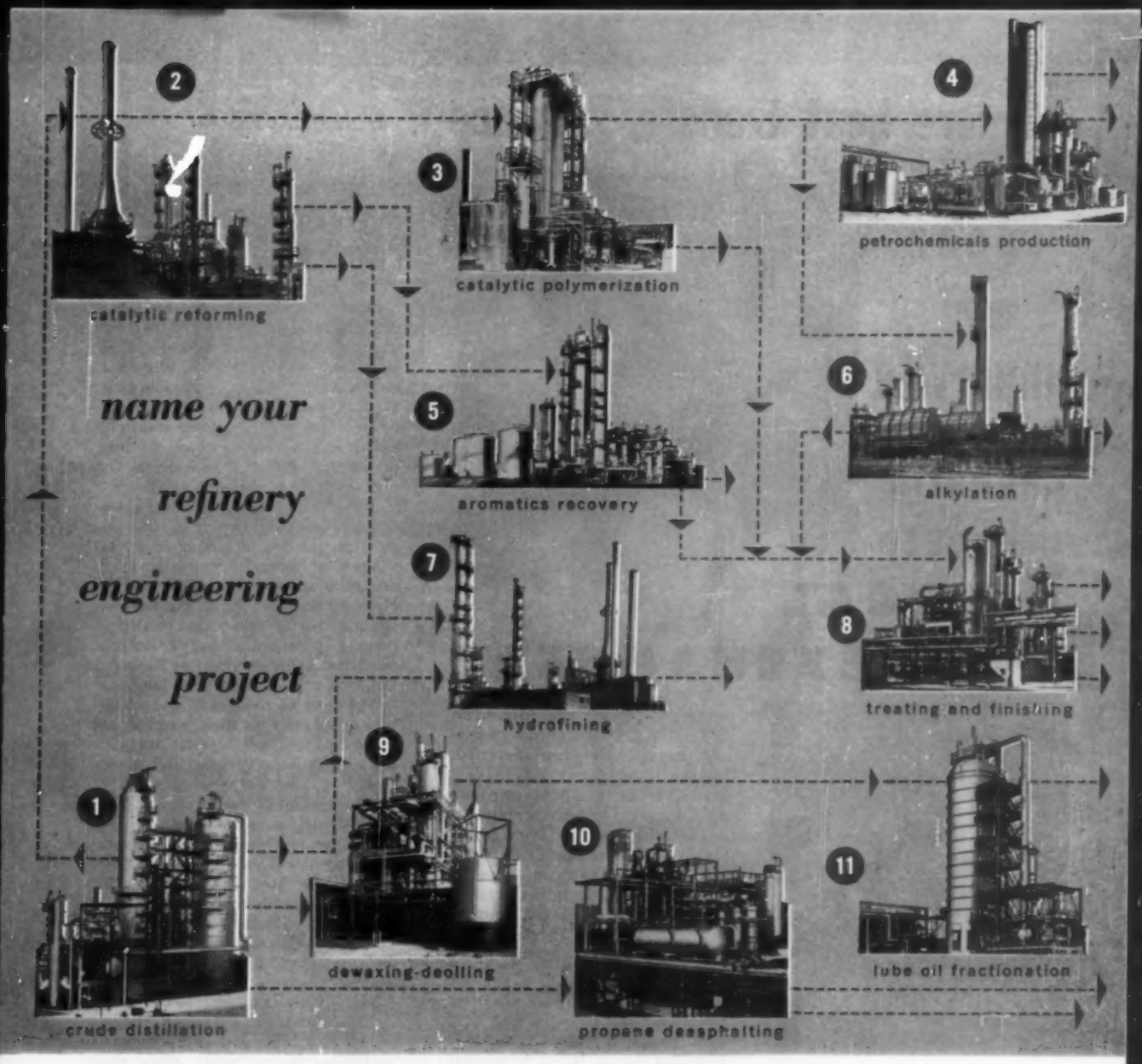
Whenever a nation undertakes to improve its way of living through modern technology it makes a commitment from which it probably cannot withdraw. The progress of a technological society such as ours is marked by constant innovation and increasingly complex interrelationships among individuals and groups. Research leading to new knowledge and its application pours out a stream of new products, with the result that each year's business involves a tremendous volume of materials that were not even known 15 years before. As this happens, the millions of people who are responsible for the production and distribution of our goods become more interdependent. It becomes increasingly important, therefore, that the over-all system be able to absorb new knowledge and put it to productive use—and that the system itself maintain its vigor so that all the groups and individuals can go on doing useful and satisfying work.

And now, if I may, a last suggestion. I would like to address a comment to my colleagues in industry. We agree, I trust, that these considerations I have been discussing are worth the interest of scientists and engineers in general and certainly, then, of professional people in industry.

We agree to this because we know that industry has been active in supporting education and in explaining its views on the challenges and needs in American education. At the same time, industry has been constructive in supporting teachers, in arguing for the return of a basic curriculum, and in urging that all qualified young people have the opportunity for a good education. We have done these things for reasons we all know.

I suggest that we continue, as individuals and as members of industry, to do this in the future, as much for ourselves as for others. The corporations we serve and benefit from are free associations operating in a free society. Their freedom and their future success are bound up with the future of other free institutions. If freedom dies for individuals or for political or social groups, it will die for corporations. What is good for our society as a whole is good for the free industries that serve it.

From a talk before the American Institute of Chemical Engineers, Philadelphia, Pa., June 23, 1958.



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Some Other Current and Recent Projects

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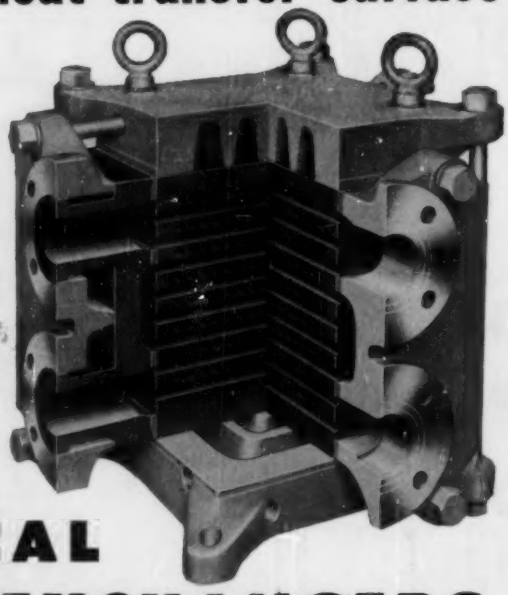

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Additions recently acquired include:

SOLID STATE PHYSICS. SUPPLEMENT 1: NUCLEAR QUADRUPOLE RESONANCE SPECTROSCOPY. T. P. Das and E. L. Hahn. Academic Press, Inc., New York, (1958), 223 pp., $7.00.

Emphasizes pure nuclear quadrupole interactions with crystalline and molecular electric fields, while placing magnetic interactions in a minor role. Part one deals with the phenomenological theory for the frequencies of the quadrupole spectra, the nature of their Zeeman patterns, the line shapes and line widths, and the relaxation times. Part two deals with the experimental apparatus required, and part three is concerned with interpretation of experimental results.

THE PROPERTIES OF GASES AND LIQUIDS: THEIR ESTIMATION AND CORRELATION. Robert C. Reid and Thomas K. Sherwood. McGraw-Hill Book Company, Inc., New York, (1958), 386 pp. $10.00.

Presents a critical review of the methods useful in estimating the important properties of pure materials and simple mixtures.

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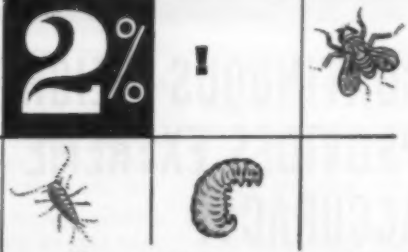
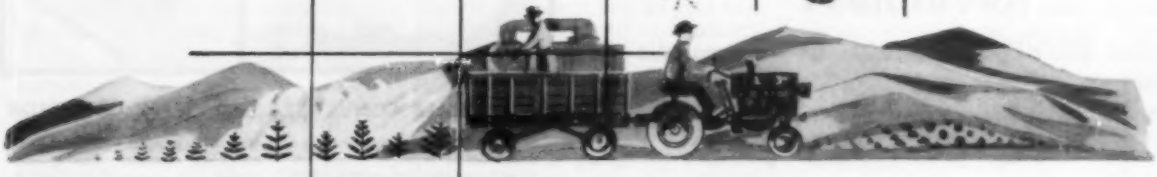
...BUT WHAT A 2% !





A recently compiled breakdown of Sulphur consumption in the United States, shows about 2% of the Sulphur goes into the manufacture of insecticides and fungicides.

Not much, perhaps, as tonnages go but no other use of Sulphur is more important with the possible exception of the 'wonder' drugs. It doesn't take much imagination to picture what would happen if the bugs and parasites were allowed to take over our crops and trees. Sulphur, along with other chemicals, is helping to protect our food supplies and foliage.

The role that TGS is playing in this constant fight against crop destruction is to see to it that the manufacturers of the insecticides and fungicides *always* have a ready supply of Sulphur, both solid and molten. This constant production and centralized distribution coupled with technical help is our contribution to industry.

SULPHUR PRODUCING UNITS

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• Moss Bluff, Texas • Worland, Wyoming
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TEXAS GULF SULPHUR CO.

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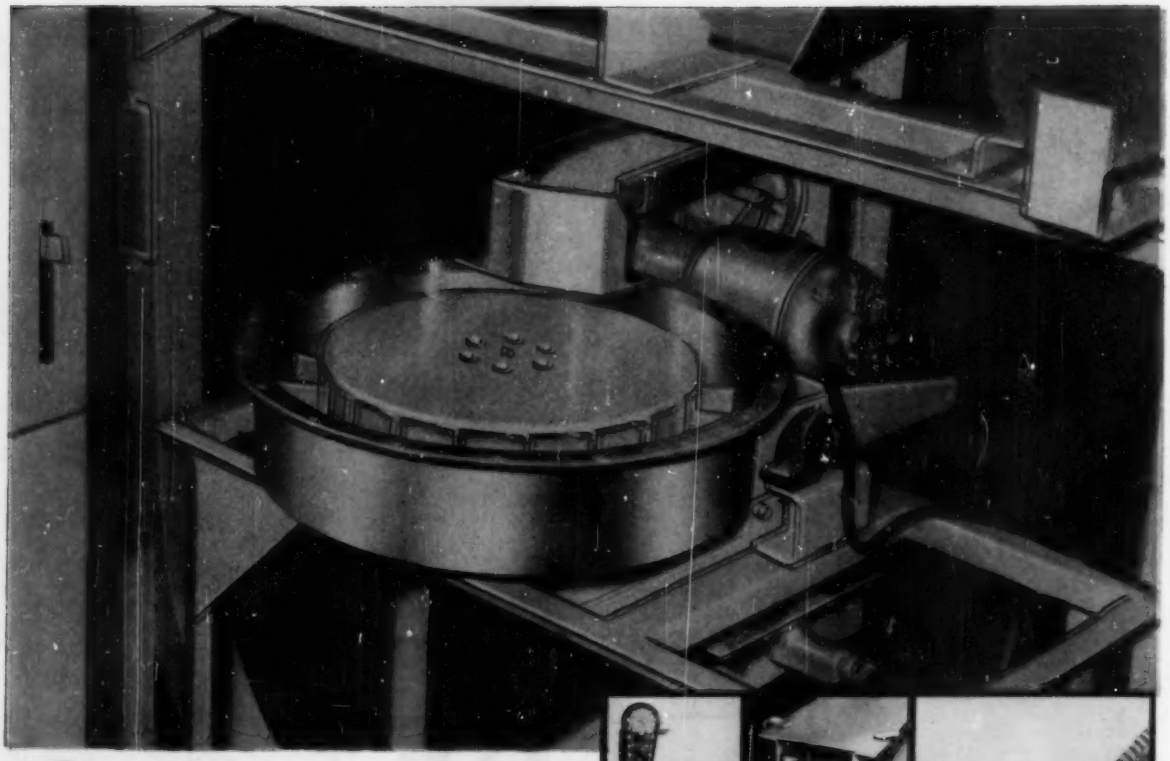
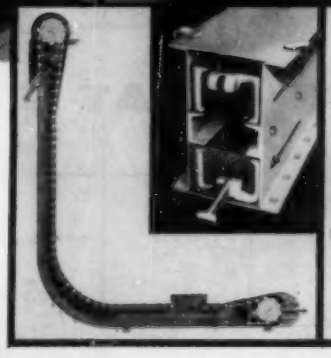


S-A CONTINUOUS WEIGHER PROVIDES EXTREME ACCURACY!

The STEPHENS-ADAMSON Continuous Weigher weighs material continuously while in motion with extreme accuracy. Material entrance and exit points are in line with pivot axis of weigher providing for easy installation within existent processing operations and completely eliminating all discharge terminal errors. The unit handles hot material with equal accuracy. Minimum headroom is required. The weigher can be adapted with control equipment for accurate gravimetric feeding without requiring extensive plant alterations. STEPHENS-ADAMSON engineers will be happy to work with you on automating your processing operations.



S-A REDLER CONVEYOR

Skeleton flights, linked together and moving through totally enclosed casings, induce the mass movement of powdered, granular or flaky bulk materials in any direction. Gentle conveying action and sealed casings mean maximum protection for materials handled. Redler units combined with Continuous Weigher offer automatic operation.

S-A ZIPPER CONVEYOR

Literally a moving, material-carrying conduct, the zipper closed belt, conveyor-elevator is capable of transporting bulk materials in any plane, to considerable heights and around obstructions. Bulk materials are conveyed free of breakage, agitation or segregation within the sealed and dustight belt. The zipper combined with Continuous Weigher is ideal for automatic feeding operations.

Write for the following bulletin:

Continuous Weigher Bulletin 958
Redler Conveyor Bulletin 556
Zipper Conveyor Bulletin 349

Sales and Engineering Offices in All Principal Cities

STEPHENS-ADAMSON MFG. CO.

GENERAL OFFICE & MAIN PLANT 57 RIDGEWAY AVENUE, AURORA, ILLINOIS
PLANTS AT: LOS ANGELES, CALIF. • CLARKSDALE, MISS. • BELLEVILLE, ONTARIO

Maintenance and Steam Traps

. . . there's a relationship that goes far beyond trap maintenance alone

Good traps and good trapping have a greater effect on your maintenance costs than does trap maintenance itself. By that we mean that the right traps, properly selected and installed, and with the benefits of a preventive maintenance program, will save far more maintenance dollars than they will cost.

Under the pressure of spiralling maintenance costs, this thought becomes mighty important. Let's take a look at what it involves:

Proper Selection of Steam Traps

1. Be sure it's the right type of trap.

2. Be sure it's sized right and is for the correct operating pressure.

3. Be sure it's first rate in design and construction.

Proper Installation of Steam Traps

1. Install them so they are accessible for inspection and maintenance.

2. Install a test valve.

3. Use a union or unions.

4. Use a shutoff valve or valves.

5. Use a strainer ahead of the trap if dirt conditions are bad.

6. Use a by-pass only where continuity of service is imperative.

7. Standardize inlet and outlet connections.

Preventive Maintenance Program

1. Test trap regularly for proper operation. (Trap size, operating pressure and importance determine frequency.)

2. Inspect internal mechanism at least once a year.

You Get Indirect Benefits As Well

The direct benefits of the plan outlined are pretty obvious — good traps, properly selected, require less maintenance . . . testing and inspection prevents troubles that lead to maintenance.

However, this plan provides indirect benefits which reduce maintenance in other parts of the plant as well:

Good traps save steam and reduce the load (and consequently maintenance) on fuel handling and burning equipment and on ash handling equipment.

Good traps protect the system by eliminating water hammer and preventing the damage it can do.

Good traps discharge carbon dioxide before it can go into solution to form corrosive carbonic acid — less corrosion, less maintenance.

Good traps increase production to reduce the length of time equipment must operate or reduce the amount of equipment needed . . . either way maintenance is reduced.

How to Go About It (The Sales Pitch)

We admit we're prejudiced, but we don't think there is any better way to select steam traps than with the help of the 44 page Armstrong Steam Trap Book. Here in a single source is specific data on the selection and sizing of traps, how to install them for best results, and how to maintain them most economically.

The Steam Trap Book will also give you full information on the design and construction of Armstrong Inverted Bucket Steam Traps that offer these important maintenance-reducing advantages:

1. Armstrong Traps are dependable.

2. Armstrong Traps require no adjustments — go from full load to zero load automatically.

3. Armstrong Traps are self-scrubbing—ordinary dirt conditions can't hurt them.

4. Armstrong Traps have long-life parts — valve and seat are heat treated chrome steel — lever assembly and bucket are stainless steel.

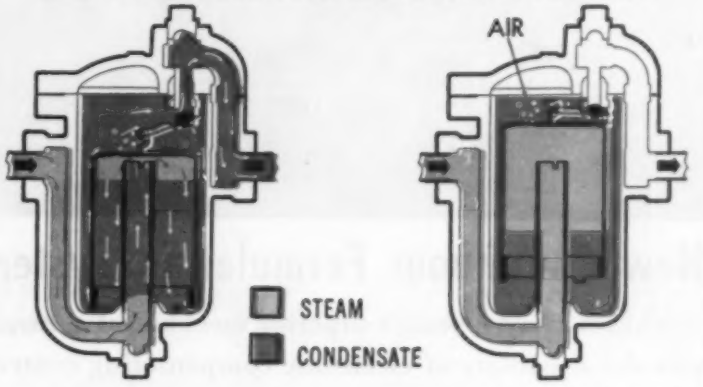
5. Armstrong Traps have water sealed valves to minimize wire drawing and erosion.

Ask for your copy of the Steam Trap Book—there is no obligation. Then test Armstrong Trapping. If you are not completely satisfied with the results, you can return the traps for a full refund of the purchase price. You can't lose much that way. Call your local Armstrong Representative or Distributor, or write

Armstrong Machine Works
9766 Maple Street
Three Rivers, Michigan

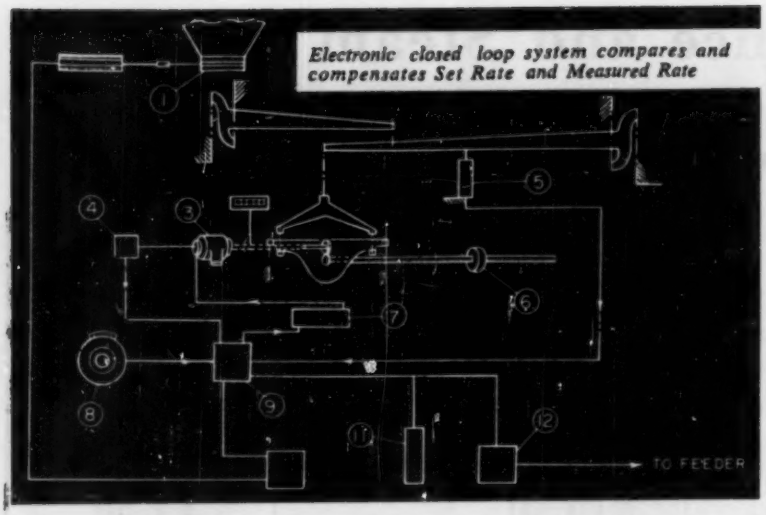
ARMSTRONG STEAM TRAPS

HERE'S THE STEAM TRAP DESIGN THAT CAN REDUCE YOUR MAINTENANCE PROBLEMS



Trap open. Condensate entering trap has caused bucket to lose buoyancy. Weight of bucket times leverage pulls valve open. Air is discharged along with condensate.

Trap closed. Steam has floated inverted bucket; valve is held tightly closed by system pressure. Air entering trap passes through bucket vent and accumulates at top of trap.



Electronic closed loop system compares and compensates Set Rate and Measured Rate

New Continuous Formulating System

Combines Thayer Scale's superior mechanical accuracy with the sensitivity of electronic compensating controls

Instantly responsive to 0.1% rate deviations in accuracy.

Thayer announces a radically new weight control system for processing hard-to-handle solids or liquids. This new loss-of-weight system provides rapid formulation with high sustained accuracy at rates up to 5 tons per hour.

Thayer Scale

A material hopper, (1) supported on a Thayer Flexure Plate Scale, is automatically filled to a selected weight and the scale is brought to balance by connecting a servo motor (3) and weight transducer (5) through a relay matrice (9). The poise (6) is then retracted, at a set rate (Dial 8), a potentiometer selects a voltage and a tachometer (4) measures the poise retraction rate. These variables are compared and differences are amplified (7) and sent to the servo motor maintaining zero error. The transducer senses deviations from balance and sends a signal to the controller (12) determining the rate of discharge. Should the system abort, an error circuit (11) will sound an alarm and interrupt the operation.

This closed loop system will maintain a constant speed control over long periods and its accuracy is not dependent upon wearing parts. The operation can be programmed by means of Thayer AUTOWEIGHTION Punch Cards. Indicators and recorders can be installed at remote locations.

THAYER FLEXURE PLATE LEVERAGE SYSTEMS are guaranteed to retain their accuracy for the life of the scale. Vulnerable knife-edge pivots are replaced by non-wearing Thayer Flexure Plates.* Neither dirt, shocks nor vibration can effect their accuracy. **Write Thayer about any problem you have controlling processes by weight.**

**Also utilized in Thayer Batching, Filling and Checkweighing Scales.*

THE Thayer SCALE

***THE THAYER SYSTEM OF PROCESS CONTROL BY WEIGHT**

AUTOWEIGHTION

THAYER SCALE CORP., 13 Thayer Park, Pembroke, Mass.

marginal notes

from page 10

CHEMICAL ENGINEERING PRACTICE. VOL. 4: FLUID STATE. Edited by Herbert W. Cremer and Trefor Davies. Academic Press, Inc., New York, (1958), 623 pp. $17.50.

Consists of three sections, the first of which deals with the thermodynamic properties of physical systems including chemical potential as a criterion of equilibrium, properties of single substances and mixtures, available work, and fluid flow. The second covers the transport properties of fluids including the flow of viscous fluids, turbulence, flow within tube and ducts, flow around objects, and compressible fluids. The last section covers measurement of process variables.

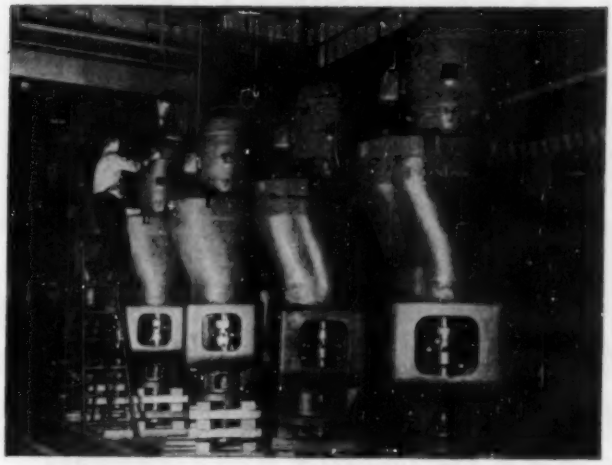
MODERN CHEMICAL PROCESSES, VOL. V. Editors of *Industrial and Engineering Chemistry*. Reinhold Publishing Corporation, New York, (1958), 154 pp. $5.00.

Career guidance booklet available. The Career Guidance Committee of A.I.Ch.E. has sponsored the publication of a booklet, *Opportunities in Chemical Engineering*. Starting with a chapter describing the origin of chemical engineering and its relation to society, the booklet covers in eight chapters all facets of chemical engineering—the field embraced, qualities required, financial return, types of work, educational requirements, related fields and professional organizations.

The booklet, while directed to the high school student, is nevertheless an excellent source of material for anyone engaged in career guidance activities. By outlining the highlights of each chapter, a 10 minute talk or a one hour speech can be readily put together. Only current pay scale information needs to be added.

Under the editorship of Chairman Ray Katzen, fourteeen members of the committee collaborated in writing the various chapters. The booklet constitutes one of the best sources of definitive information on the chemical engineering profession pertinent to the counseling of high school students.

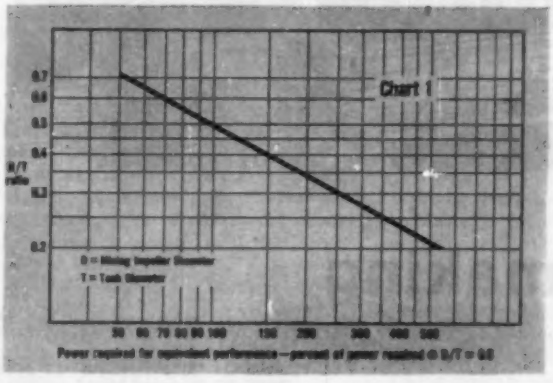
Opportunities in Chemical Engineering may be obtained from, Vocational Guidance Manuals, 1011 East Tremont Avenue, New York 60, New York. Price: $1.00 per copy.



Q. In larger mixing operations, what are the economics of buying mixers that match requirements *exactly* compared to buying mixers having an adequate margin of torque capacity?

A. As mixing operations are scaled up and fluid mixers required increase in size, the cost per unit drive torque capacity decreases rapidly with the increase in drive size. It becomes poor economy not to maintain an adequate level of torque applied to the mixing operation. Consider also that agitators and auxiliaries rarely represent more than a small percentage (2-4%) of the plant investment . . . yet maintenance costs on the more difficult operations can run as high as 15% or 20%. If down time is considered, then costs can run many times these figures. Obviously, there is no economy in drives and components such as shafts which *just* meet requirements.

it's questions like these... that bring out the facts in buying mixers...



Q. Are "dollars per horsepower" a valid basis for comparing mixer values?

A. No. Mixers having the same horsepower rating and drive efficiency can vary widely in torque rating. Torque applied to the mix is what does the work and torque is what you pay for. When comparing mixer values, the most important first step is that of developing torque ratings of alternate units offered. Using the most familiar units, torque can be calculated as follows:

$$\text{Torque (lb. inches)} = \frac{63025 \times \text{Motor HP}}{\text{Mixer shaft RPM}}$$

The mixer having the lower torque rating must use a higher mixer shaft speed and smaller diameter impeller to maintain a given HP level. This can lead to unsatisfactory performance. However, a mixer of equivalent horsepower rating but with a higher torque rating and larger impeller will do the job well. For an idea of the importance of impeller size, the chart shows the influence of impeller diameter in relation to tank diameter (D/T ratio) upon motor required to obtain a specific level of performance in many industrial mixing operations. The bigger impeller at the slower speed (higher applied torque) will be a sounder choice.

YOU GET MORE FOR YOUR FLUID MIXER DOLLAR

Because We Design and Build The *Whole* Unit

It's simple economics! Philadelphia Mixer is the only manufacturer that designs and builds the complete unit. Because we control production and costs, we can afford to give you more mixer per dollar. For example:

- Extra large, heavy duty bearings throughout.
- Extremely heavy output shafting—machined, ground and polished.
- Drives designed with extra strength and rigidity to take maximum thrust and unbalanced loads.

You don't pay a premium for these extras—or for the better performance and longer life of a Philadelphia Mixer. You get them as a bonus.

You can select your Philadelphia Mixer from six standard models. 1 to 200 HP. Special units to 500 HP. Horizontal motor or vertical motor drive. Mechanical seal or packed stuffing box. Paddle or turbine type impellers.

Get the full story on Philadelphia Mixers. Write for Catalog A-27. It contains complete mechanical design information that permits you to make a catalog selection of the mixer that best suits your requirements.

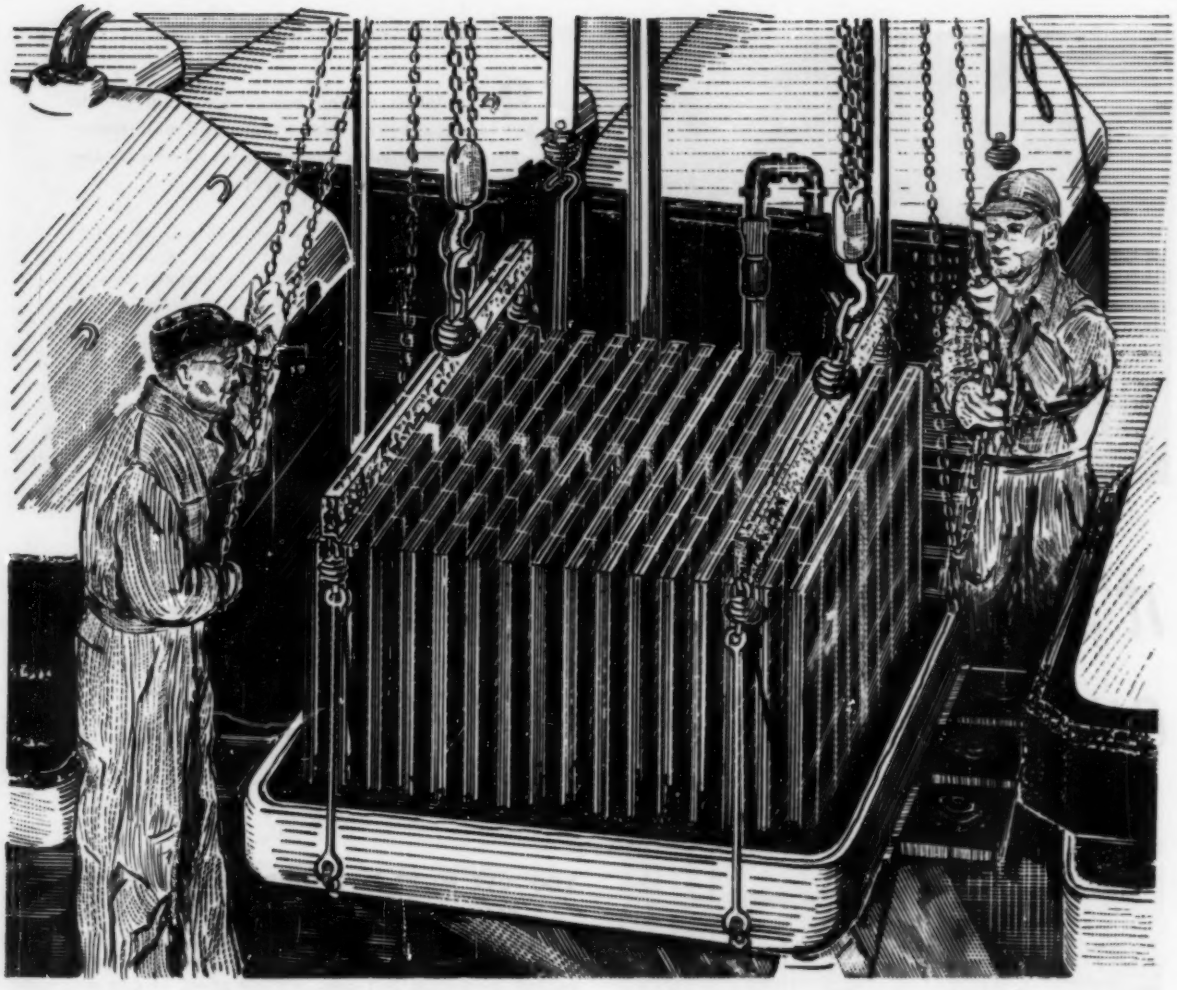
PHILADELPHIA GEAR CORPORATION

Erie Avenue and G Street • Philadelphia 34, Pennsylvania

philadelphia mixers

Offices in all Principal Cities

INDUSTRIAL GEARS & SPEED REDUCERS • LIMITORQUE VALVE CONTROLS • FLUID MIXERS • FLEXIBLE COUPLINGS



Efficiency in the making

Depth of experience in the building, installation and operation of Hooker cells is a highly important factor in their production efficiency.

High efficiency is also a characteristic of **GLC Anodes,** which are "custom made" to individual cell requirements.

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ELECTRODE GLC® DIVISION

GREAT LAKES CARBON CORPORATION

18 EAST 48TH STREET, NEW YORK 17, N.Y. OFFICES IN PRINCIPAL CITIES

Progress Report...

— CELLOSIZE HEC 4400
— Ethylene oxide
— Quality control

Making latex paints easier to use

Additives help those popular latex paints go on easily and spread well. Additives also increase shelf life in warehouse or store, improve pigment distribution, and give better resistance to temperature changes.

One important, effective thickener for latex paints is water-soluble, nonionic CELLOSIZE Hydroxyethyl Cellulose 4400. Paint processors get better production schedules with CELLOSIZE HEC, because it goes into solution easily and quickly, and has low-foaming characteristics. It is possible to add CELLOSIZE WP-4400 directly to the pigment grind, and thus avoid preparation of a separate thickener solution. Clear, bright colors are obtained because color variations are eliminated or greatly reduced.

Stable viscosity, good scrub resistance and excellent flowout are other desirable features of latex paints compounded with CELLOSIZE WP-4400.

For more information on thickeners, plasticizers, dispersants, stabilizers, and other CARBIDE additives, check the coupon to get the booklet, "Chemicals for Resin Emulsions."

Nonionic detergents from ethylene oxide

Continuing demands for low-foaming detergents call for another look at ethylene oxide as an economical base for nonionic surfactants.

No newcomer to the field, CARBIDE's ethylene oxide has been the starting point for various nonionic surfactants for more than 20 years. Powdered or liquid detergents, for light or heavy duty, can be produced from ethylene oxide derivatives. Such compounds have excellent wetting properties, ability to disperse grease, and a tendency to stabilize foaming. Nonionics derived from ethylene oxide with other reactants are stable in acid or alkaline aqueous systems and are compatible with both anionic and cationic surfactants.

Two types of surfactants can be produced by reactions involving ethylene oxide. Surface active esters result from reacting ethylene oxide with tall oil or rosin acids, or other hydrophobic acids:—

$$RCOOH + x(C_2H_4O) \rightarrow RCOO(C_2H_4O)_xH$$

Ether surfactants are made by the reaction of ethylene oxide with alkylphenols, higher aliphatic alcohols, mercaptans, or propylene oxide polymers:—

$$R\langle\rangle OH + x(C_2H_4O) \rightarrow R\langle\rangle O(C_2H_4O)_xH$$

$$ROH + x(C_2H_4O) \rightarrow RO(C_2H_4O)_xH$$

$$RSH + x(C_2H_4O) \rightarrow RS(C_2H_4O)_xH$$

$$x(CH_2C_2H_4O) + y(C_2H_4O) + ROH \rightarrow RO(CHCH_2O)_x(C_2H_4O)_yH$$

$$CH_3$$

Applications for detergents produced from ethylene oxide are found in domestic washing machines and dishwashers, utensil cleansers, and scouring compounds. Commercial establishments use them for large volume laundering, dry cleaning, rug and upholstery cleaning, restaurant dishwashing, and for scrubbing large surfaces.

Information on (1) handling and operating methods when using ethylene oxide, (2) data on TERGITOL nonionic surfactants for detergents, and (3) a 64-page booklet on ethers and oxides is available. Check the coupon.

How quality is maintained at CARBIDE

Close supervision during every step of processing assures CARBIDE's customers of highest quality chemicals—from the point where natural gas enters its plants to the shipping platforms.

At the gas pumping stations, a continuous check is maintained to make certain that CARBIDE's raw material streams meet strict standards. As they are separated, components are analyzed by mass spectrometer. While being processed, material samples undergo careful chemical analysis. Certain materials in process are further examined with a vapor fractometer, or other appropriate equipment.

Finished materials are subjected to strenuous performance tests, for each of CARBIDE's products must fulfill the expected requirements of customers. Even during loading operations, the final product is rechecked for purity—with an emission spectograph, for example – to make sure it contains no metallic impurities.

And all the while, CARBIDE's Quality Control Laboratories study better testing methods and more advanced scientific devices to assure customers of consistently highest quality.

Tear out this coupon. Check the boxes on which you'd like more information, and mail to Dept., H, Union Carbide Chemicals Company, 30 East 42nd Street, New York 17, N.Y.

☐ Chemicals for Resin Emulsions. ☐ Ethylene Oxide—handling and operating methods. ☐ TERGITOL. ☐ Ethers and Oxides.

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And remember, there is a CARBIDE sales office near you where you can obtain the services of a CARBIDE Technical Representative. His wide industry experience is backed by both extensive chemical training and by Technical Specialists.

"Cellosize", "Tergitol", and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

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QUICK COUPLINGS
for safe transfer of your products

Here's proof EVER-TITE excels in
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Superior quality forged body —precision machined
Uniform wall thickness —no weak spots
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Stainless Steel pins —greater safety and longer service
Uniform heavy wall thickness —no weak spots
Recess retains gasket in coupler and assures proper placement
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Get a QUICK COUPLE every time

You can *speed work—prevent leakage—save wear on equipment* by using an EVER-TITE in every operation that calls for couplings. Ever-Tite always gives you tight, quick connections because Ever-Tite has positive gasket compression that is dependable under *all* conditions. Get Ever-Tites—get a *quick, safe, tight* couple every time. Ever-Tites are available in:

STAINLESS STEEL
Aluminum • Malleable Iron • Brass
Other materials on request
Send for full details now

Chain for attaching Dust Caps on Dust Plugs to adapters or couplers

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NEWS PLUS INTERPRETATION

SCOPE

International Polypropylene Battle Shapes Up

"Montecatini is the exclusive owner and controls the licensing all over the world of the patents and patent applications on Professor Giulio Natta's sterically differentiated polypropylenes and stereo-specific propylene polymerization processes," says Bartolomeo Orsoni, head of Montecatini's New Projects and Development Division. "The only exception is Germany, where Montecatini has granted exclusive rights to Professor Karl Ziegler of the Max Planck Institute Fuer Kohlenforschung of Muelheim-Ruhr."

"The developments of Professor Ziegler in the high olefin polymer field," continues Orsoni, "are subsequent to Montecatini's basic inventions in polypropylene and other higher olefins. Moreover, the later Ziegler developments in the higher olefin field relate only to a process which yields polymerizates of practically no commercial interest."

Getting down to the implications of these claims, Orsoni went on to say— "Professor Ziegler has licensed Hoechst in Germany to manufacture polypropylene. Hoechst in turn has sold its know-how to Hercules Powder Co. in the United States. Hercules is now manufacturing commercial polypropylene (of the type disclosed by Natta) in the United States without any license agreement with Montecatini. Hoechst does not have any rights under Montecatini's patents to sublicense any company in the United States. Basic patent applications on Natta's polypropylene developments are still pending at the U.S. Patent Office."

Queried by CEP, a spokesman for Hercules said— "Hercules has not sought or obtained a sub-license from Hoechst under any Montecatini patents on polypropylene. No U.S. patents have issued to Montecatini relating to stereospecific polypropylene or its manufacture. Hercules has developed its own process of manufacture and Hoechst has shared in its development. This development was *not* based upon any Montecatini patent rights or know-how."

Contacted to help clarify the present situation further, and give Prof. Ziegler's position in the matter, Montecatini and Prof. Ziegler issued the following joint statement:

"According to an existing Montecatini-Ziegler agreement, Ziegler has exclusive rights on Polypropylene in Germany and Montecatini has exclusive rights on Polypropylene in Italy. Montecatini's and Ziegler's patent rights outside Italy and Germany are licensed by Montecatini according to said Montecatini-Ziegler agreement.

"Montecatini negotiates patent licenses taking into consideration Ziegler's wishes, final decisions being reserved to Montecatini, which retains the major share of the returns.

"This agreement was reached after the following developments had taken place: Montecatini became in January 1953 one of the earliest licensees of Ziegler's pioneer developments on organometallic catalysts. Ziegler's 1953 invention of new complex organometallic catalysts and of the possibility of polymerizing ethylene to high polymers with the aid of them was disclosed by Montecatini in December 1953. Shortly after this disclosure, Prof. Natta, Montecatini's consultant, working with Ziegler-type catalysts, succeeded in discovering sterically differentiated polypropylenes and somewhat later he discovered stereospecific catalysts and invented his stereospecific propylene polymerization processes.

"Hercules and the four other U.S. Companies which have acquired licenses from Ziegler prior to the Montecatini-Ziegler agreement (which licenses do not entail any rights on Montecatini's patent rights) have not yet acquired Montecatini's patent rights on Polypropylene."

Is a legal battle shaping up? Neither side has given any indication of direct action. At stake, however, is not only the position of Hercules, but that of other U.S. companies known to be working on polypropylene processes. Added complication is Montecatini's announced decision to build a 60,000 ton/year plant at Brindisi, Italy, for the production of copolymers of ethylene and propylene. (Finished products made of the new copolymer were exhibited by Montecatini at the recent Plastics Show in Chicago). With Montecatini seemingly again first in the field with commercial production of an important group of plastics, it is not unlikely that another clouded patent situation may develop, analogous to that now existing in the case of polypropylene.

Dow Chemical contracts to buy Russian benzene

About 27 million gallons of benzene from the Soviet Union will be purchased over the next two years by Dow Chemical at a price approximately 6 cents a gallon under current U.S. quotations. The purchase contract calls for payment in Dutch guilders through Dow's Dutch subsidiary, Nederlandsche Dow Maatschappij M.V. Imports of benzene from behind the Iron Curtain have been blamed for a decrease in the U.S. market price last summer (CEP, November, 1958, Scope, p. 21).

SCOPE

Can We Afford Basic Research?

"Our universities and research foundations in the past have been the strongholds of pure research," said L. G. Bliss, president of Foote Mineral Co., at the recent MCA meeting in New York. "Today the pressures of industry have forced them more and more into applied, rather than pure, research."

"The resulting deficiency of pure research," according to Bliss, "may threaten our safety as a nation and our health as an industry . . . It is doubtful if industrial research laboratories can afford to develop sufficient fundamental scientific information to compete on the international scene."

Bliss estimates that national research expenditures will reach $15 billion by 1960—an average of 3% of the cost of products sold. "Research," he said, "has become a major item of expense, and the cost is increasing rapidly." The speaker went on to tell his audience that the effective deployment of research dollars and personnel is one of the chemical industry's knottiest problems. Urging an industry-wide study on how to increase research effectiveness, Bliss recommended that the Manufacturing Chemists Association (MCA) study this entire question of the allocation of research dollars and research talent. He suggested, also, cooperative sponsorship of pure research programs as a possible solution.

A slightly different tack was taken by J. S. Murray of American Potash and Chemical, who told a panel at the MCA New York meeting that the Government should provide the necessary incentives to attract industrial resources into increased research efforts. Said Murray—"One way to provide a long-term incentive is through the handling of patents resulting from research so that the research institution can obtain certain exclusive rights for a prescribed period."

There are indications that the United States may be putting too great a strain on its economy by overemphasis on applied research and development, says Fritz Machlup, Johns Hopkins economist, writing in *Science* (published by the American Association for the Advancement of Science). According to Machlup, there are three principal factors in a nation's economy which compete for its human resources. Two of these factors are production of capital goods and production of consumer goods. The third, he says, is production of knowledge, which he divides into three parts: basic research; education; and applied research. Basic research, according to Machlup's theory, does not draw too heavily on our human reserves; education and applied research, however, are bitter competitors for trained personnel. It is possible, he suggests, that the poor showing, personnel-wise, made lately by education may be in part due to the fact that applied research has been getting more than its share of the nation's human resources.

Saturation effort needed

There is little ground for doubt but that an all-out "saturation" effort is needed to tide our nation—and for that matter the Western World—through the critical times we are presently experiencing. So concluded a recent A.I.Ch.E.-sponsored panel* which was concerned primarily with, "Where is the money coming from."

Henry Eyring, dean of Utah University's Graduate School, now believes "saturation" to be a "must." "Further," continues Eyring, "I believe we can attain it in a practical sense, and that we can afford it."

"Saturation in basic research," defines the National Science Foundation's W. G. Colman, "is attained when no competent scientist who wants to and is qualified to perform basic research work, is precluded from doing so for reasons of financial support.

Labelling of basic research projects as to "defense" or "peaceful" is impractical, states Research Corporations Joseph W. Barker, "One simply cannot predict which application may turn out to be the most important." Barker cites long experience which indicates periodic reviews provide the basis for determining which projects appear to be shaping towards desirable goals.

"Industry is forced to undertake rigorous reviewing of its research projects, as its reason for being done by industrial firms is because its essential to a good balance sheet," stressed Union Carbide's Gus B. Kinzel. To be so essential, Kinzel warned, "industrial research must be closely related to one's own business."

As to where the money is coming from, Barker feels that more should come from industry—which not only benefits in the long run, but can presently contribute (on the average) a good deal more than it does and still stay within the limits permitted by Internal Revenue.

* *Panel on Financing Research, Salt Lake National A.I.Ch.E. Meeting, Sept., 1958.*

Correction

In Scope, November, 1958, page 19, it was erroneously reported that A.I.Ch.E. had filed a brief as a friend of the court in the Spevack case. The brief was actually filed by EJC at the instigation of A.I.Ch.E.

Technical executives seen in increased demand

According to results of a survey by Hoff, Canny, Bowen & Associates, New York executive placement firm, a big boom is on the way for highpaid ($15,000 and up) scientific executives. The boom is predicted to begin in 1959-60 and to be in high gear by 1964-65. Chemistry, electronics, and atomic energy will offer the greatest financial rewards, area of best opportunity will be the Mid-West, says the placement firm.

SCOPE

U.S.—EURATOM Agreement on Atomic Energy

Nuclear power reactor types developed in the United States will be the design basis for the erection of plants with a total capacity of some 1 million electrical kilowatts within the six nations making up the European Atomic Energy Community (EURATOM).

A formal agreement between the United States and EURATOM (Belgium, France, West Germany, Italy, The Netherlands, Luxembourg) was signed in November, awaits only ratification by the new Congress which convenes in January, 1959, to become effective.

Main provisions of the agreement are:

"Financial guarantees by the United States of up to $90 million for a 10-year operating period with respect to the cost and integrity of the fuel elements required in the reactors;

"Long-term assurance of an adequate nuclear fuel supply at prices equivalent to those offered to domestic U.S. industry;

"Guarantee for a 10-year period of a market for the plutonium recovered from the power reactors in the program;

"Long-term credits of up to $135 million to cover a portion of the capital costs of the nuclear power plants;

"A long-term assurance by the United States that chemical reprocessing services will be available under terms comparable to those then available to U.S. industry."

Capital cost of the whole program, excluding fuel, is expected to be in the neighborhood of $350 million. Question in the minds of U.S. firms in the nuclear field is bound to be—how big a slice of the design and construction pie will come their way? The answer seems to be that, while much of the design work will undoubtedly be done in the U.S., no bonanza is seen in the cards by American equipment fabricators, according to advices received by CEP. It is the reported intent of AEC that construction and operation of the projected plants be entirely in the hands of utility groups (either publicly—or privately-owned) in the various EURATOM countries. Such groups will submit bids, limited only by the provision that they must be based on U.S. reactor types already in an advanced stage of development. (This provision would seem to limit the available types to three-pressurized water, boiling water, or, perhaps an organic-moderated type).

Although the U.S. has agreed to advance $135 million toward the capital cost of the plants (probably through the Export-Import Bank), it is not expected that any attempt will be made to apply "Buy American" provisions in respect to purchase of equipment. According to one of the large American companies in the nuclear field, the fact that the U.S. Government is loaning money for the projects, does not constitute a guarantee that American design firms would necessarily be paid in dollars. It is pointed out that forced purchase of American equipment, if more expensive, would tend to defeat one of the main objectives of the whole program—to demonstrate the economic feasibility of nuclear power in Europe. Thus, it may be anticipated that most of the conventional equipment will be of European origin. On the other hand, this development may well tend to encourage more U.S. fabricators and constructors to establish branches within the European Community.

Great Britain has no part in the U.S.–EURATOM agreement. However, no U.S. monopoly is looked for in the reactor export business according to one U.S. firm: British terms offered to Italy, for example, are said to be almost identical with those now offered by AEC under the Euratom agreement, including fuel element and reprocessing guarantees. Other competition with U.S. firms does not seem imminent at the present moment. French development work is not believed far enough advanced to contemplate export and, to date, the Russians have made no bid in the world market.

Washington Notes

The chemical industry may anticipate a somewhat larger share of the government dollar, according to certain Washington sources, which point to a significant diversion of aircraft engine money to rocket motor money. . . . *Complete information on services and facilities on tap in the Patent Office* will soon be available to anyone with a new idea, thanks to a new Office of Information Services just established within the Patent Office. Director of the new service will be Isaac Fleischmann, formerly head of the Patent Office training branch . . . *Paul D. Foote has retired as Assistant Secretary of Defense* for Research and Engineering after more than fifteen years of service in the Federal Government . . . *A new "nozzle" process for isotope separation,* developed at the University of Marburg, Germany, is reportedly under investigation at the University of California under AEC sponsorship. Economic feasibility of the method, however, is said to be doubtful due to the extremely low pressure at which the separation takes place . . . *Inquiries and license applications relating to export of process equipment to the Soviet Union* indicate that the promise of "billions of dollars" of process equipment business contained in the much-publicized letter of last June from Khrushchev to President Eisenhower was "a typical Russian exaggeration," said recently Frank W. Sheaffer, Acting Director of Export Supply, Bureau of Foreign Commerce, U. S. Dept. of Commerce. According to Sheaffer, up to the present, only a few licenses have been issued for significant plants. Major technical data licenses to date have been for plants for production of synthetic fibers, textile plants, and tinning and galvanizing facilities. —*J. L. Gillman, Jr.*

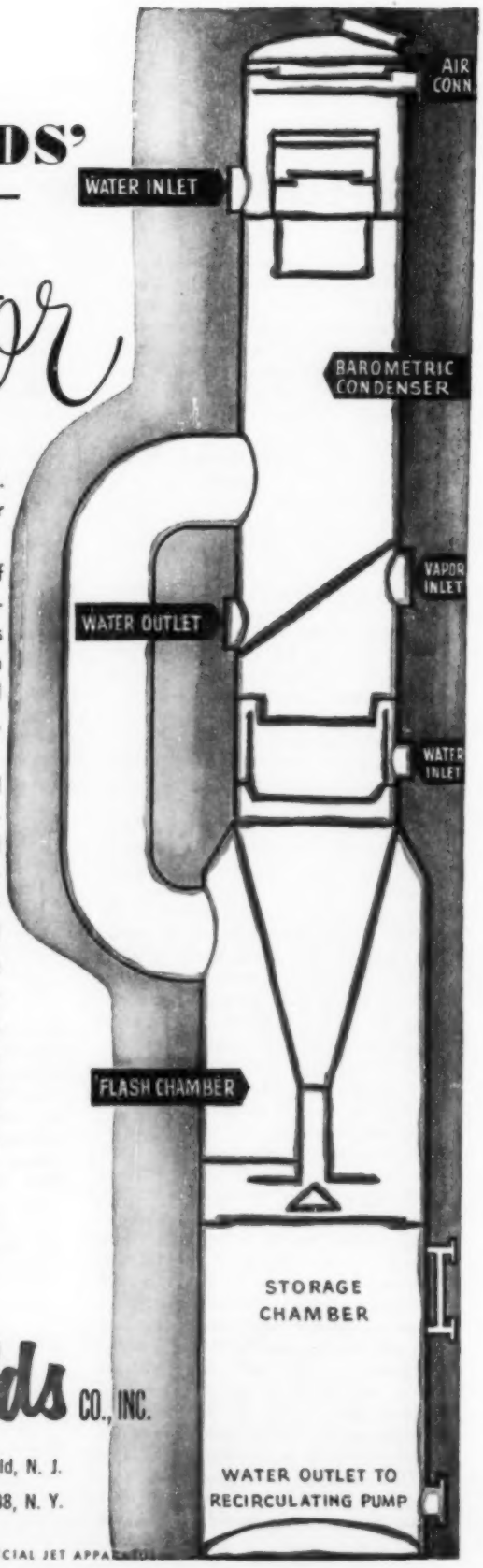
CROLL-REYNOLDS' NEW Convactor

If you never heard of a CONVACTOR, do not be surprised. It is an entirely new design of special condensing tower which offers important advantages in some processes.

In the refining of edible oils it recovers fatty acids, most of which were formerly waste. It offers the additional advantage of totally eliminating stream pollution from this source or the expense of cleaning cooling towers which collect such deposits. It has similar application in fatty acid stills, some other types of distillation processes, dryers, and other large vacuum processing units.

The CONVACTOR is a combination of two condensers and a vacuum cooling chamber. One condenser is of conventional barometric design, the other a highly improved condenser working on the jet principle. The latter condenses the vapor from the process and discharges directly into the vacuum cooling compartment where the heat of condensation is immediately removed. The cold water is then recirculated through the same jet condenser. The flashed vapor from the cooling operation is condensed in a conventional barometric condenser using water from a river, cooling tower or other industrial source. Periodic blow-down or continuous bleed-off from the flash chamber permits recovery. Several large industrial installations have been made.

Patent applied for



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NEW PELLET COOLER AND DRYER

Modification of the patented Rotaircool®, developed for the economical cooling, drying and conveying of pellets, has been recently announced.

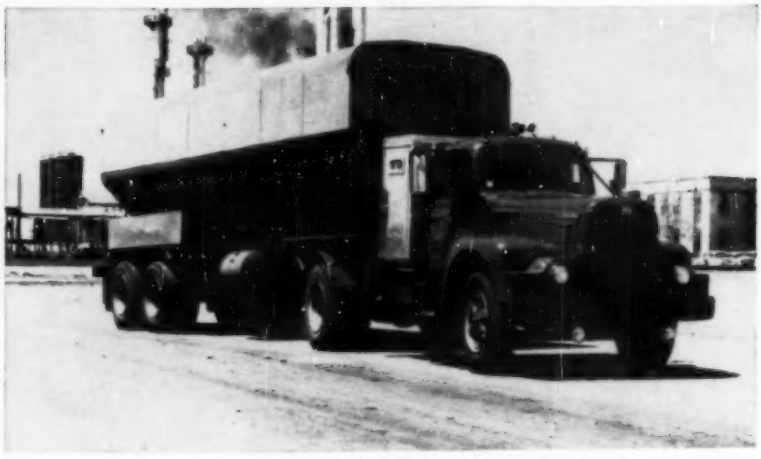
Major redesign feature is the use of a compact rotary airlock feeder beneath the tank to receive the cool or dried pellets and discharge them as required. Handling of the pellets from the pelleter to the inlet of the Rotaircool is by means of the Sprout-Waldron Pneu-Vac® negative pressure air handling system which keeps pellet breakage, dust and maintenance at a minimum.

Sprout-Waldron Industrial Rotaircool for cooling, drying and pneumatic conveying of pellets.

By adding heating coils just prior to the pellet inlet, the Rotaircool® system is equally adaptable for heating or cooling. Further details in Bulletin 202.

PRACTICAL PNEUMATIC CONVEYOR DESIGN

A technical article by the Chief Engineer of our Materials Handling Division. It tells how to select, operate and maintain pneumatic systems for transporting dry, bulk materials. Positive, negative and combination systems are illustrated and described. Ask for Bulletin I-28.



One of five Sprout-Waldron Pneumatic Aluminum Bulk Trucks for handling polystyrene pellets in Cosden Petroleum's new "curb service marketing" delivery concept. Note Cosden's modern 32,000 barrel custom refinery in background.

SPROUT-WALDRON BULK TRUCK HANDLES POLYSTYRENE PELLETS

A recent announcement by officials at Cosden Petroleum Corporation, Big Spring, Texas of a new delivery concept, "curb service marketing" is arousing considerable interest throughout the plastic industries. The revolutionary marketing plan involves a delivery of polystrene pellets by special highway transports direct from the purchasing plant to the customer.

The key to the new concept is a group of five 28' pneumatic aluminum bulk trailer units designed and built by Sprout-Waldron. Each of these trailers has a capacity of 1,182 cubic feet which is equivalent to 34,000 lbs. of polystyrene pellets. The high powered unloading system permits delivery to the customer at the rate of 30 tons per hour. Delivery and storage in bulk cuts down on fringe expenses such as unloading, warehousing, multiple handling and contamination. Bulk storage also permits instant inventory determination. Storage bins can be located at the most suitable point in the plant since the pneumatic unloading system built into the trucks permits delivery anywhere a pipe can be run.

Recent completion of the new polystyrene plant is said to make Cosden Petroleum the first producer able to integrate all phases in the manufacture of this basic material. Both general purpose crystal polystyrene and high impact polystyrene are being produced. The styrene monomer used in manufacturing polystyrene is produced in an adjacent plant also owned and operated by Cosden.

CP/108

Portrait of a Scientific Ambassador

Back in 1936, a young graduate student of engineering was offered a scholarship for study in France and in Germany. He accepted. Today, this fortuitous decision, succeeded by innumerable visits to Europe as student and then professor, has culminated in the appointment of Edgar L. Piret as Principal Science Officer at the U.S. Embassy in Paris.

Returning to the U.S. in 1937 with a doctorate from the University of Nancy, France, Piret went on to earn a Ph.D. in chemical engineering at the University of Minnesota, where he is presently professor of chemical engineering. Succeeding years, marked by a distinguished academic and industrial career (Piret has been chief chemical engineer and consultant for a large mining and chemical company), have in no wise diminished his interest in European culture and science.

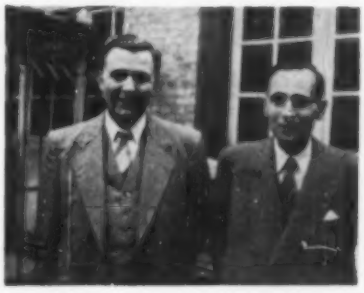
1936: Early international days for Piret as a graduate engineering student at Heidelberg.

In 1950, Piret was appointed Fulbright Research Professor at the Universities of Paris and Nancy, France. He emerged with the Friedel Medal of the University of Paris, and was named Officier d'Academie, Palmes Academiques, French Ministry of Education. For his services to the French educational system, particularly for his part in the introduction of modern chemical engineering curricula into the French universities, Piret, in 1957, was made a Chevalier of the Legion of Honor. Not mentioned in the official citation, however, was a much more personal consideration: Over the years, Piret has made it his own business to help European graduate students, both French and of other nationalities, to find the means and the funds to come to the United States for study. According to his own estimate, such students number more than twenty-five, and he is presently arranging such fellowships for a group of Japanese students.

Engineering societies in Holland and Sweden, in 1954, invited Piret to lecture in their countries on chemical engineering research techniques. In appreciation, he was awarded the Bronze Medal of the Swedish Association of Engineers.

Fluent in the French language, Piret will be completely at home in Paris, where he expects to be settled by next April (with his wife and five children). An interesting sidelight is that the Piret daughters (12, 10, and 8) will be eligible to attend a school just outside Paris which was founded by Napoleon for the children of Legion of Honor winners.

Today: With Mrs. Piret and the family. The new "ambassador" will use the experience of his long-time international study and work in a vital post, will take the family with him.



1950: Piret with Prof. Paul Lafitte of the Chemistry Dept. of the Sorbonne in Paris.

The appointment as principal science officer in Paris is viewed by Piret as a "challenging" assignment. He sees it as an opportunity to advance scientific knowledge and to maintain peace by stimulating better communication and better cooperation between the scientists and engineers of the world.

Scientific attache program

Filling a long-felt need, the State Department has just announced assignment of a group of eminent American scientists to serve as scientific attachés in United States embassies abroad. This group is the vanguard of a total of eighteen to be appointed (in pairs) to various important embassies — London, Paris, Bonn, Stockholm, New Delhi, Tokyo, Rome, Moscow, and probably Rio de Janeiro.

Our new scientific representatives will be considered more as diplomats than as researchers or "diggers" for specific scientific information, emphasizes L. H. Farinholt, Deputy Science Advisor, Department of State. They will be expected to act as advisors to the ambassador and to represent the United States as delegates to a wide variety of scientific meetings and other scientific gatherings—a great deal of speech-making will no doubt be involved, says Farinholt. They will promote exchange of scientific and engineering information between foreign scientific organizations and indi-

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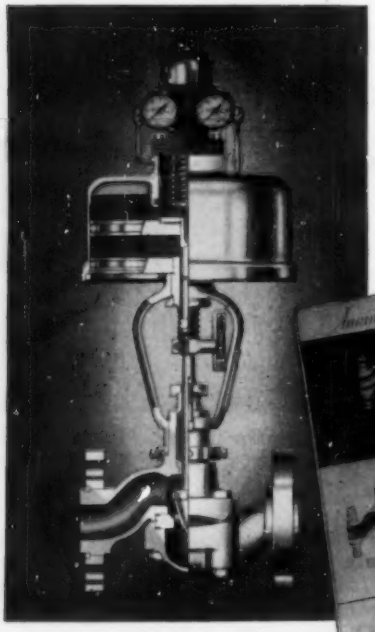

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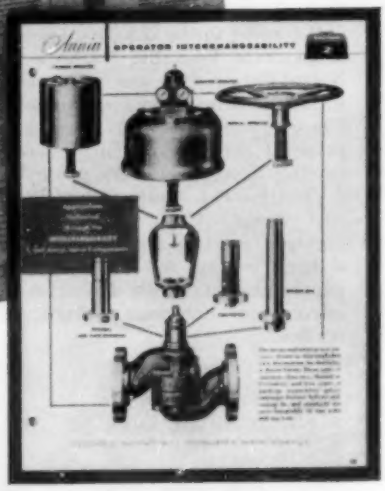

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No other process control valve offers the advantages in economy and adaptability as that provided by the Annin valve. The split body eliminates pockets and shoulders that create undesirable turbulence and accumulated solids, reduces erosion and allows consistent flow behavior with a wide range of fluids under all conditions.

Superior body design permits conversion in any alloy from the basic Globe Body to Corner, Angle or 3-way construction.

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Three basic Annin operators bring new and improved performance. The DOMOTOR operator is the most responsive, precise positioning and fastest pneumatic operator available... Electro-pneumatic or pneumatic CYLINDER operators, for remote shut-off applications, are designed to withstand continuous "on-off" operations... MANUAL operators, for precise throttling of flow rate and tight closure.

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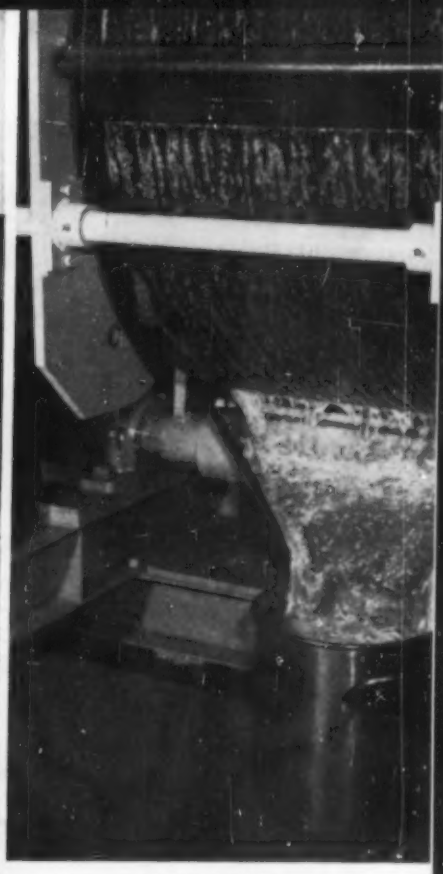

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An extensive line of small scale and pilot-size equipment is at your service for investigating drying, evaporation, extraction, impregnation and crystallization problems. Here you obtain accurate data and actual samples of your processed product, examine operation efficiency . . . thoroughly explore by-product possibilities.

Catalog 384 describes the Buflovak Dryer line; Catalog 381 fully describes Buflovak's lab. Both are available at your request. Additional facts also available in C. E. Catalog, pages 429 to 452.

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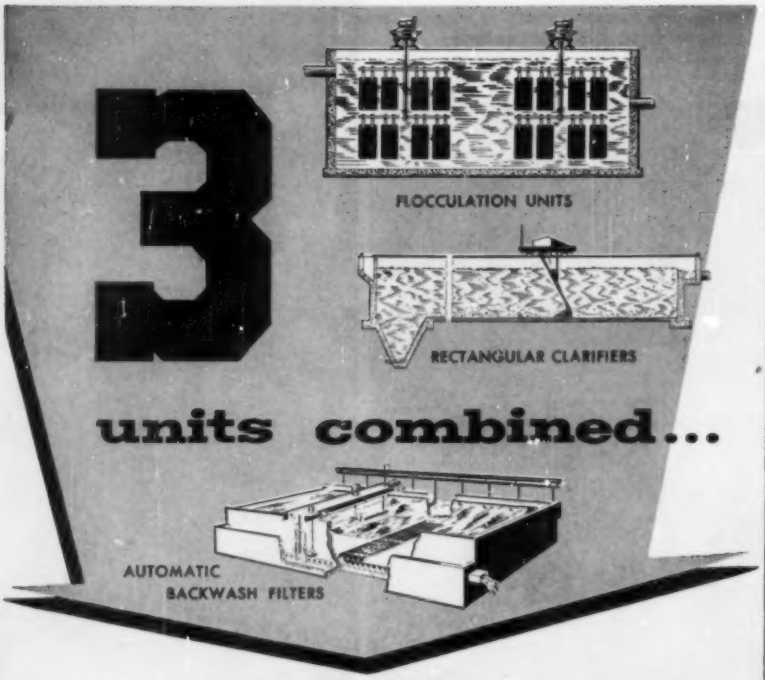

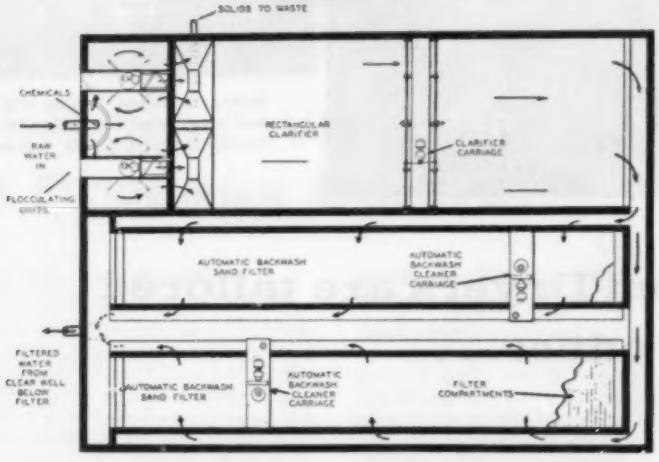

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about our authors

J. R. Fair, who teamed up with **W. L. Bolles** and **W. R. Nisbet** to write this month's article on *Ethylene Purification-Demethanization,* has been active in the design and evaluation of ethylene processes over a period of about fifteen years. An interesting part of this experience was the rebuilding of one of Monsanto's ethylene plants in Texas City which had been severely damaged in the disaster of 1947. According to Fair, it took "a bit of doing" to piece together salvaged equipment with a minimum of new equipment, at the same time incorporating new design features.

Ludwig Kniel, who writes on *Low-Temperature Demethanization — the Advantages,* is with the Lummus Co., New York, and **R. J. McGarry** *(30 Decisions Favoring Low-Temperature Demethanization)* is affiliated with Stone & Webster Engineering, also of New York.

R. E. Reitmeier *(Acetylene Removal from Polyethylene-Grade Ethylene)* describes himself as a specialist in production of heterogeneous catalysts, especially in the field of synthesis gas production, special hydrogenations, and desulfurization. In 1957, he formed a new company, Catalysts and Chemicals, Inc., of which he is now president. Reitmeier's co-author is **H. W. Fleming,** also of Catalysts and Chemicals.

Authors: Fair, Davison, Hays.

The authors of *Process Design of Ethylene—Ethane Fractionator,* **J. W. Davison** and **G. E. Hays,** (both with Phillips Petroleum) worked jointly for a number of years conducting process and economic studies on ethylene production; these studies ultimately led to their company's entry into the field of high purity ethylene production. The present paper, say the authors, was intended to serve as a means of making quick evaluations of ethylene fractionator situations preliminary to a detailed design or evaluation of the selected case.

W. M. Swanson and **C. H. Watkins** *(High Purity Aromatics—Bonus of Ethylene Process)* are both with Universal Oil Products, Des Plaines, Illinois.

continued on page 30

POWELL

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Fig. 2442AL — Aluminum O. S. & Y. Gate Valve for 100 W. P. at 350F. Especially advantageous in laboratories and process plants for piping distilled water and handling acetic and nitric acids. Flanged end valves also available.

Fig. 2600 — New 150-pound Bronze Full Flow Globe Valve. 500 Brinell hardened, stainless seat ring and disc. Nominal pipe size seat opening and extra high lift of disc assure full flow with minimum pressure drop and turbulence. Can be supplied with indicator collar and arm for visual control. 200 and 300 pound valves also available.

Small Flush Bottom Tank Valves for 150 W. P. made in two designs. Fig. 2172 disc opens into tank; Fig. 2173 disc opens into valve. Available in a number of metals and alloys; also for 300 and 600 W. P.

Fig. 2343 — Swing Check Valve for 150 W. P. Bolted Cap. Made in Monel Metal, Nickel and Hastelloy Alloys B-C, and with flanged ends. Valves of this design can also be furnished in stainless steels.

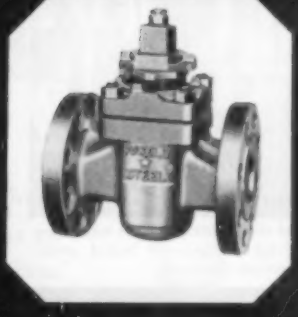

Fig. 1559 — Steel Lubricated Plug Valve for 200 pounds, W. O. G.—A. S. A. 150 pounds. Screwed gland type. Single gland and bolted gland types also available. Large valves—6" and above—can be supplied with gears for gear operation.

Fig. 2107BSW — (Sectional)—Stainless Steel Bellowseal "Y" Valve for 150 W. P. Designed for high vacuum service—for controlling the flow of heavy water, molten metals and all hazardous, lethal and malodorous fluids.

*and in this family there's a valve for every flow control requirement—for handling water, oil, gas, air, steam and corrosive fluids—available in the most required sizes and types. If your local distributor can't supply you, or if you need specially engineered valves for unusual conditions, write

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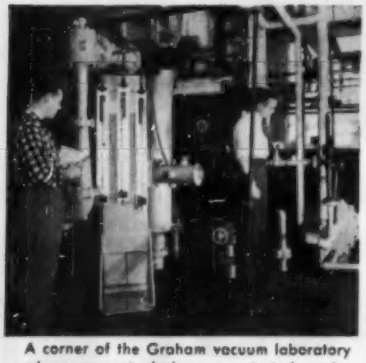
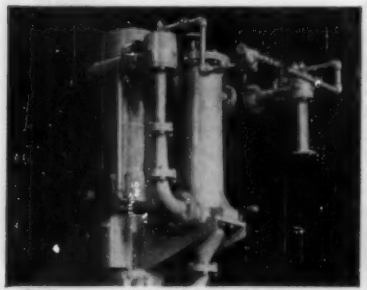
Graham Steam Jet Ejectors have served industry for over *one quarter of a century* and our installation list reads like the blue book of America.

Graham Research at Batavia, New York is constantly exploring new features that insure you the most modern design and performance in vacuum equipment.

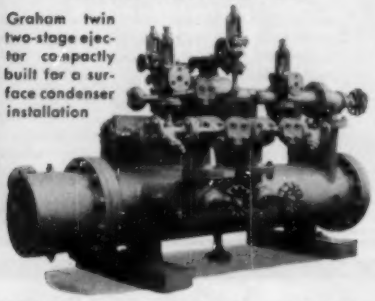


A corner of the Graham vacuum laboratory where current designs are tested under actual operating conditions



Graham two-stage ejector with barometric inter-condenser in distillation service

Write for our Bulletin 70-A



Graham twin two-stage ejector compactly built for a surface condenser installation

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about our authors

from page 28

D. A. Dahlstrom is director of the Research and Development Department, Eimco Corp. His article this month (written with **D. E. Matschke**), is Part I of an exhaustive study of *Miniature Hydroclones — Energy Requirements and Solid Elimination Efficiency.*

D. E. Garrett, author of this month's article on *Industrial Crystallization at Trona,* is with American Potash & Chemical Corp.

Authors: Hutto, Bell, Reitmeier.

G. R. Bell and **F. B. Hutto,** both with Johns-Manville, contribute this month an article on *New Concepts in the Analysis of Rotary Precoat Filter Operation.* Bell joined Johns-Manville in 1942, and in 1944 was transferred from the Celite Division to the Johns-Manville Research Center where he has specialized in filtration problems since that time. Hutto joined Johns-Manville's Celite Application Research Center in 1952, and has been chiefly concerned with basic filtration techniques including development of test methods and equipment.

Scientific attache

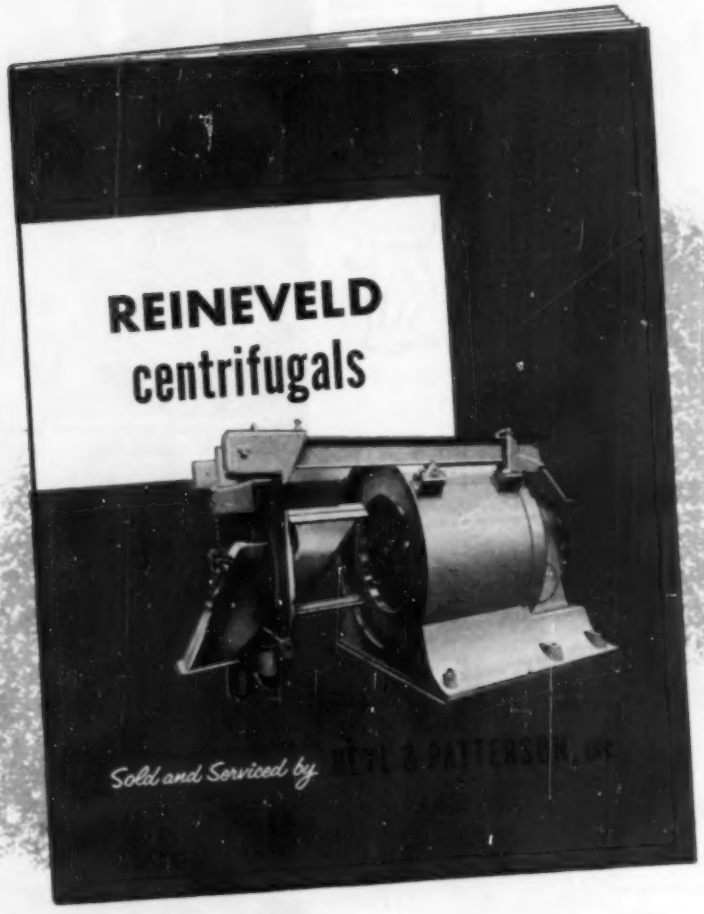
from page 25

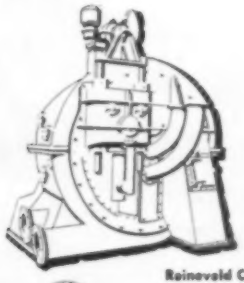
vidual scientists and their counterparts in the U.S. In addition, they will be responsible for reporting and evaluating significant trends in the scientific life of the countries to which they are assigned.

The job of finding the right man for the right post has not been easy, say State Department officials. Every effort has been and is being made to choose distinguished scientists who will uphold and enhance American scientific prestige abroad.

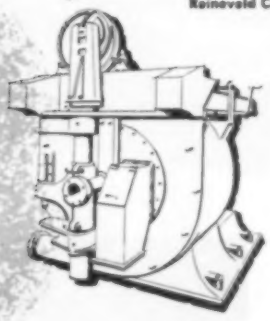
The program has been under the direction of Wallace R. Brode, formerly associate director of the National Bureau of Standards, who was sworn in last January as State Department Science Advisor.

For the Engineer's File...

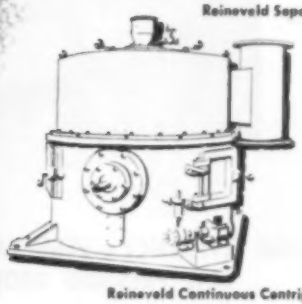




Reineveld Centrifuge



Reineveld Separator



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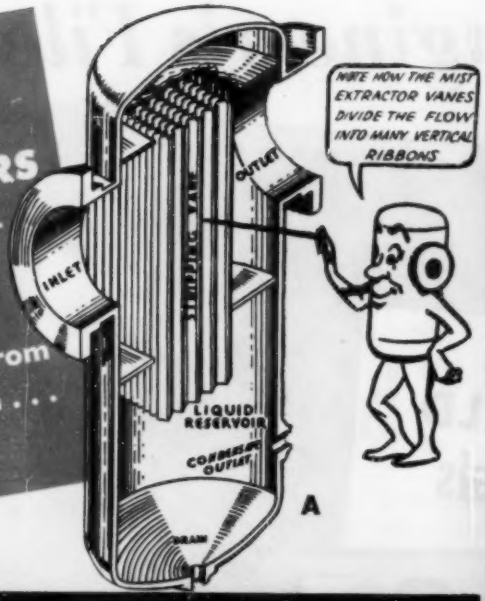

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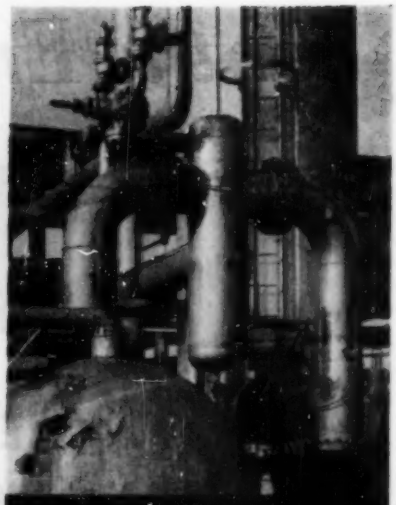
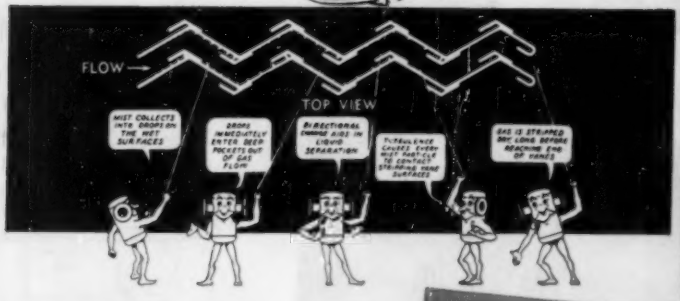


A Peerless Line Separator is shown above removing entrainment from a refinery reboiler.

B


FLOW
TOP VIEW
MIST COLLECTS INTO DROPS ON THE WET SURFACES
DROPS IMMEDIATELY ENTER DEEP POCKETS OUT OF GAS FLOW
BI-DIRECTIONAL CHANGE AIDS IN LIQUID SEPARATION
TURBULENCE CAUSES EVERY MIST PARTICLE TO CONTACT STRIKING VANE SURFACES
GAS IS STRIPPED DRY LONG BEFORE REACHING END OF VANES

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Drawing A above shows the arrangement of the vanes in the Separator. Drawing B is an illustration of the Peerless principle.

The mist extractor combines the forces of impingement, centrifugal motion and surface tension to obtain its high efficiency. The path of the gas, etc., through the unit is constantly bending, causing semi-violent turbulence and rolling of the gas against the walls of the vane. Impingement and centrifugal force combine to contact the droplets with the vanes, where they coalesce, and surface tension then causes them to cling to the vanes' surfaces. Gravity and the impact of the gas stream then drives the droplets into the pockets where they roll down the vanes and out of the gas stream.

Through the Peerless method of mist extraction, the gas is stripped dry long before reaching the end of the vanes.

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For any vapor-liquid ratio
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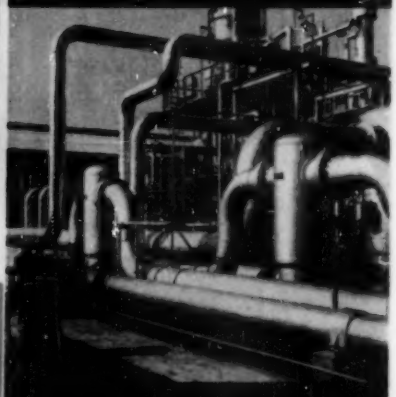

Peerless Line Separators are doing an effective job of mist extraction at this Kentucky Petrochemical Plant.

This is an insulated Peerless Steam Separator on a turbine driving an airblower.

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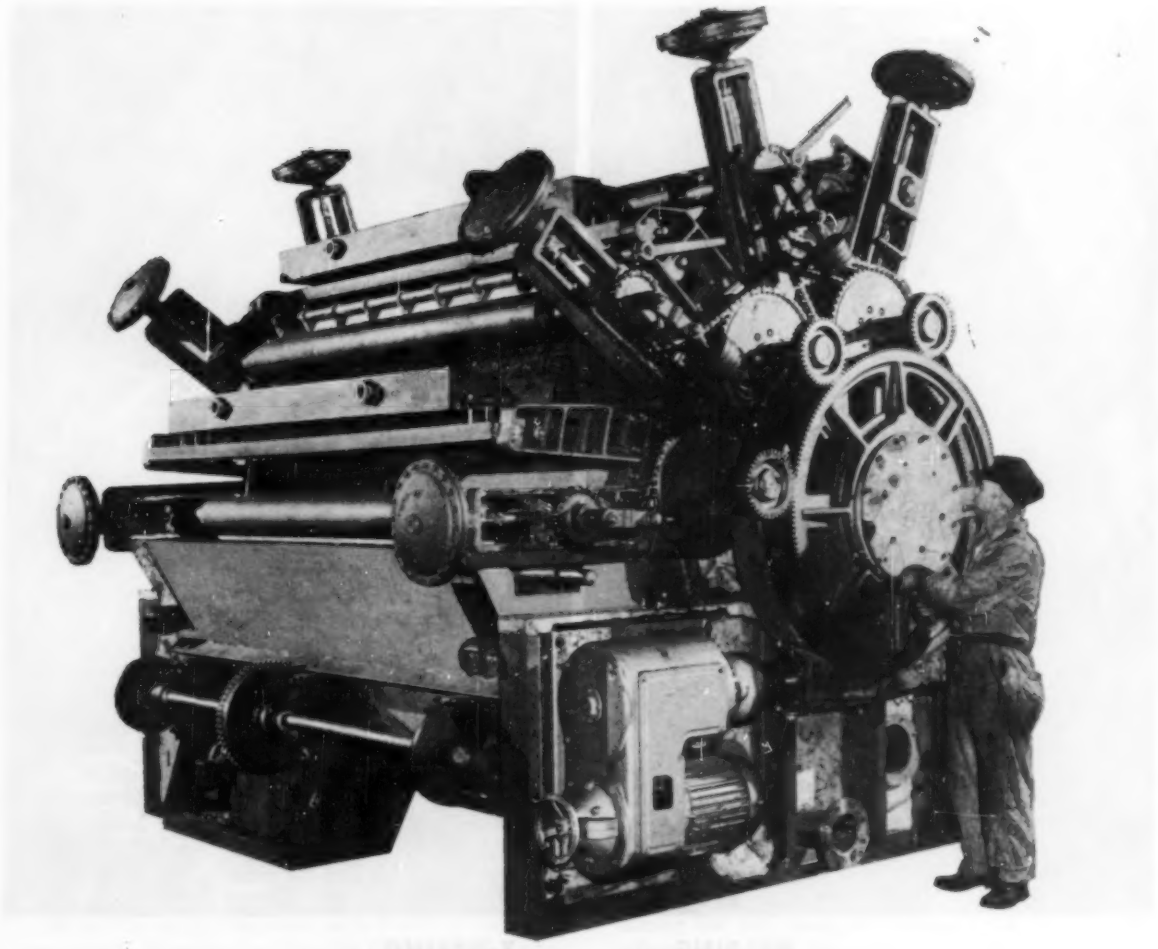

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B - 355

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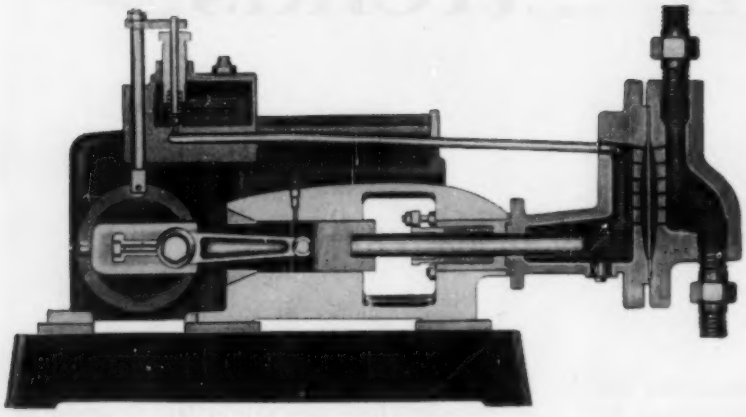
Chemical business in sharp turn-up

Business recovery continues with indications that December will see the most favorable levels of the year. This will mean that earnings statements for the quarter will be the best of any three month period of the year, and will make a specially favorable comparison with the final months of 1958 when the recession was at its worst. Business of many of the larger chemical companies was turned up sharply and is still improving so that earnings for the year will be considerably larger than expected a month or so ago, and, of course, much above the gloomy forecasts made last spring when the turn had not yet come.

Operating profits margins have also widened due to urgent and drastic economies put into effect after business went on the skids a year ago. Much of the cost saving, of course, came as a result of reducing personnel. However few firms in the chemical group laid off engineers or scientists. In the main they postponed salary increases. In some instances severance pay cut into earnings temporarily. A sizeable segment of the chemical industry is looking forward to record sales in 1959 and the more fortunate firms are hoping for a few high records in earnings, provided partly as a result of larger sales and partly because of improved profit margins. Charges for authorization and depreciation of plants, which have been rising steadily for the past decade, are expected to level out so that earnings will start to improve instead of being held back by rising charges. The chemical industry still has a great deal of excess capacity which will ultimately be the base for a sharp increase in profits. Meanwhile, much of the industry's plant is operating at only about 65% of capacity and some is as low as 35% to 40% capacity which means operations are in the red. Some of the newer plastics such as American Cyanamid's Methyl styrene and Hercules Powder's polypropylene have been very slow in getting started partly because of the reluctance of molders to retool or undertake new ventures in a recession. Next year should see improvement in a number of these newer lines. One factor larger firms might take into account is the mobility and flexibility of some of the industry's baby firms. By giving faster and more "personalized service" these little boys seem able to stand up against the giants, even in some competitive fields. One of the great basic factors that should make for improving business over the next year or so is the record high level of personal savings accounts. While this is not money that will necessarily be spent, it provides stability and releases consumers from unreasonable fears. This offsets installment debt often regarded as a danger hanging over the economy. Retail sales are holding up and record department store sales are expected. Motor sales are slowly improving, building is increasing and steel operations are rising.

Stock market

The stock market continued to hold the spotlight during the fall, rising to unexpectedly high levels, followed, in late November, by the most drastic reaction seen in several years. Several factors have been behind the advance, first the still improving business outlook, then the underlying fear of long range inflation, the heavy buying by funds and institutions who confine their buying largely to a selected list of blue chips, and finally the comparative scarce supply of these prime issues. Most institutions buy to hold for several years or more but this does not mean that they do not lighten holdings if stocks move up in a few months as much as they had been expected to move in a year or more. Individuals are much better long-pull holders of stocks than is generally believed outside of the comparatively small trading fraternity. This has contributed to the narrowing supply of gilt edged stocks. Another factor is employees stock purchase plans, which in the aggregate tie up a great many shares. There is at least one major chemical company where 90% of employees are stockholders. This policy means that companies are provided with a moderate but steady supply of new capital year by year without going to the public for money. Rises in the stock market, if sustained, help the wealth of individuals in firms but naturally do not help the corporations except to provide higher selling prices for new shares in the event of public financing.



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opinion and comment

Standards in the chemical industry

Standards for equipment primarily intended for chemical process service are important and beneficial to the chemical industry. In spite of its age, the chemical industry stands to gain extensively from standards just now being formulated, or even planned. It is conservatively estimated that the industry will save up to $6.8 million annually (an average of $200 per installed unit) from centrifugal pumps being planned with interchangeable connections, etc. Another $3.9 million may well be realized from standardized heat exchangers, and $2 million from thin-wall carbon steel pipe.

The same estimators claim up to $20 million annual direct savings —which includes both labor and materials—if the chemical industry were to have adequate and uniform standards available for most of the process plant construction and maintenance materials and equipment items it must buy.

The American Standards Association (ASA) is the organization set up to bring user and producer into a practical working arrangement by which mutually acceptable American Standards can be developed.

Eight years ago—in 1950—the Chemical Industry Advisory Board was set up within the framework of ASA for the purpose of getting the chemical industry conscious of standards pertaining to its interests. The CIAB is made up of representatives from national professional and trade associations, not from individual companies. Of its representative-members, the A.I.Ch.E., Chlorine Institute, Compressed Gas Association, Manufacturing Chemists Association, and the Society of Plastics Industry may be said to be representing the interests of the chemical industry. Like any other organization, the CIAB is limited directly by its budget, and indirectly by the number of supporting groups interested in, and contributing towards, its work. Up to the present, only a small proportion of the 150 or so eligible chemical companies have company memberships in ASA. This is in spite of the fact that the annual dues for ASA's company memberships are nominal —ranging upwards from a minimum of $200/yr. Such dues are based on annual sales, which means that a firm grossing $100 million annually pays something of the order of $1,500 annually for its ASA company membership.

Why has interest in CIAB on the part of a large number of chemical firms, lagged? Some admit that no really concerted efforts have been made to generate such support.

Today, the CIAB has become concerned about this situation, and is asking that (1) at this time of extensive interest in cost reduction much more serious attention be directed by the chemical industry to the development of American Standards as an important factor in reducing costs in the future, and (2) this attention be backed by more firms taking out the ASA company memberships.

Certainly the cost of investment in dues will be returned many-fold. Then too, the investment in personnel made available for ASA committee work on standards for the chemical industry will go far to provide for the development, within the company structures, of attitudes and procedures for rapid utilization of standards as they come along. J. B. M.

How large can a Packed Column be ?

Up until a relatively few years ago packed columns in excess of 8 feet to 10 feet in diameter were generally restricted to specific operations such as gas drying or water cooling. In liquid-liquid extraction, in distillation, diameters of packed columns beyond 4 feet were considered impractical and uneconomical.

Today, due to the development of more efficient tower packings (such as Intalox Saddles and metal Pall Rings) and more effective methods of distribution, there is virtually no limit to the diameter of an efficient packed column.

We know of two towers 53 feet in diameter with packed beds 26 feet deep. Scrubbing towers 25 feet or more in diameter are becoming quite common. And in distillation operations where perforated trays or bubble caps had been almost universally specified for columns larger than 4 feet, packed columns 10 feet to 12 feet or more in diameter are being used with increasing frequency.

In operations involving Absorption, Stripping, Cooling, Fractionation, Distillation or Liquid-Liquid Extraction, the packed column offers greater efficiency at lower installation and operating costs in virtually any size.

333-F

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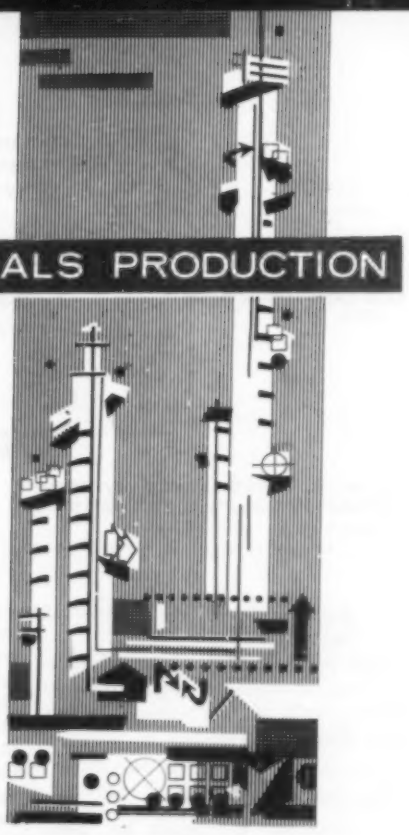

Ethylene purification —*demethanization*

December **CEP** feature

J. R. Fair, W. L. Bolles, and W. R. Nisbet
Monsanto Chemical Company

Commercial production of ethylene is based on the thermal or catalytic decompesition of petroleum hydrocarbons. The products from the decomposition reaction have an ethylene content of 30 mole % or less, and for most end uses this purity must be upgraded to 90% or higher. The recovery and purification facilities so required represent a major portion of the ethylene plant investment cost.

The raw material for an ethylene recovery system normally is a gas containing hydrogen plus light hydrocarbons in the C_1 - C_5 range. In addition, inerts such as nitrogen and carbon monoxide may be present. This feed gas may be derived from various petroleum refinery sources, or it may be produced within the confines of the ethylene plant by the pyrolysis of selected feedstocks. Regardless of source, there will be included in the gas two fractions: one comprising methane and lighter materials, and the other comprising ethylene and heavier materials. Probably the most expensive step of the several in the over-all process of ethylene recovery is the separation between these two fractions. This separation step is known as *demethanization*.

This article is devoted to the technology of demethanization. It is basic that the design of facilities for this step must be tailored to the particular raw material gas available; indeed, a wide variety of designs is in present commercial use. In the final analysis the "best" design must result from detailed studies involving productive capacities, special processing requirements, and local economics.

General considerations

The composition of the feed to the recovery system can vary widely, depending upon source. In Table 1 typical feed streams are shown, with their source noted. Although these data represent actual operating analyses, they should be construed as general and subject to variation depending upon pyrolysis conditions, refinery gas sources, and other factors. Furthermore, the data are based on the assumption that prefractionation or condensation facilities have been used to remove the majority of C_5 and heavier components present in the raw gas*.

The sharpness of separation between the key components methane and ethylene is governed by the following economic considerations:

1. Ethylene lost with the methane is rejected to a fuel gas system, at less than a tenth of its value as product ethylene.
2. Methane carried through with the ethylene results in increased refrigeration requirements and remains as a diluent in the product ethylene, in some cases

continued on next page

J. R. Fair is in Dayton, Ohio; W. L. Bolles in El Dorado, Ark., and W. R. Nisbet in Texas City, Tex.

**Preremoval of unsaturated C_4 and heavier materials is desirable for recovery systems in which no polymerization of these materials can be tolerated.*

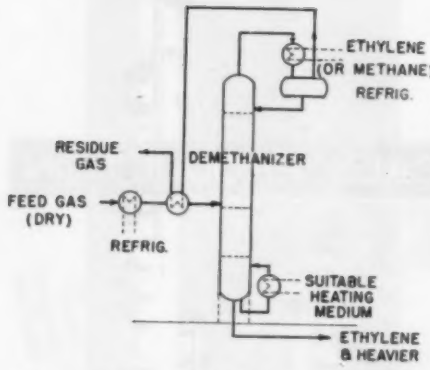

Figure 1. Demethanization by straight fractionation (100-150 and 450-600 lb./sq. in. abs.)

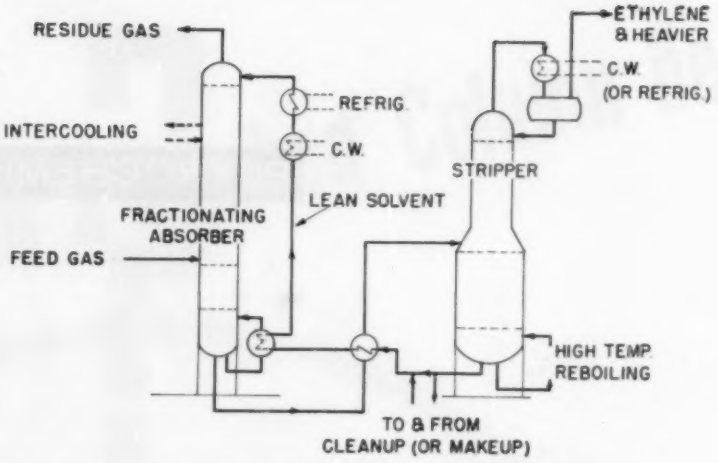

Figure 2. Demethanization by aromatic absorption-stripping

requiring special final removal facilities.

These considerations are in addition to those dictated by thermodynamic relationships as functions of system operating conditions.

Process descriptions

Commercial techniques for demethanization are conveniently placed in three main categories:

1. Straight fractionation
2. Absorption-stripping
3. Selective adsorption

For reader orientation and for a comparison of the processes, it is convenient for these techniques to be discussed separately, with technical details included.

Fractionation. Demethanization by straight fractionation is accomplished in a single distillation column. Since the critical temperature of ethylene is 49°F., refrigeration to some degree is necessary in order to condense ethylene reflux for the column. For reasons to be shown later, a great deal of refrigeration is required in practice, and the head temperature of the distillation column is in the range of −140 to −250°F. Thus, design problems for the straight fractionation method are centered around the low-temperature processing requirements.

For purposes of description, it is convenient to classify commercial fractionation demethanization processes according to operating pressure level. The most popular level in the United States is 450-600 lb./sq. in. abs. Two other levels are important and have found acceptance primarily outside the U.S., namely 100-150 and 30-40 lb./sq. in. abs. A generalized flow diagram for the fractionation method is given in Figure 1.

1. *Operation at 450-600 lb./sq. in. abs.* Compressed feed gas, from which the majority of C_5 and heavier components have been removed, is chilled to 50-60°F. by heat exchange with a high-level refrigerant. This operation results in the condensation of most of the water vapor contained in the feed; the residual water vapor is then removed by passing the gas through a bed of solid desiccant. Further cooling of the feed is obtained by heat exchange with the demethanizer overhead product and, in some cases, by evaporating low-level refrigerant. The feed temperature at the column is usually below 0°F. and for some designs is as low as −75°F.

The demethanizer is a conventional bubble-cap or sieve tray column, heavily insulated and provided with nickel or chromium-nickel steel for temperature environments below −20°F.* Product ethylene is ordinarily used as a refrigerant for condensing reflux for the column; since the atmospheric boiling point of ethylene is −155°F., and since general practice is to avoid vacuum in ethylene refrigeration systems, column top temperatures are limited to a minimum of about −140°F. The net overhead product is removed as a vapor and may be expanded adiabatically or isentropically to lower its temperature and recover additional ethylene. Finally, the overhead stream is warmed by heat exchange with the feed, and rejected to the fuel system or to processing units which utilize the hydrogen content.

The demethanizer bottoms temperature ranges from 50 to 100°F., depending upon bottoms composition and degree of methane stripping desired. Reboil vapors are supplied by heat exchange with low-pressure steam, condensing refrigerant, or hot water. The net bottoms stream, containing ethylene and heavier components, plus minor amounts of methane, is further processed for ethylene purification.

Economics in the U. S. usually dictate this 450-600 lb./sq. in. abs. operating range, if straight fractiona-

It is possible to specify carbon steel for temperatures as low as −75°F. Aluminum-killed steel meeting appropriate impact tests is required.

Table 1. Typical Demethanization Feed Gases (Mole %)

Source	Ethane pyrolysis	Propane pyrolysis	n-Butane pyrolysis	Nat'l gasoline pyrolysis	Gas oil pyrolysis	Typical refinery gas
H_2	36.7	16.1	8.4	10.5	13.2	28.7*
CH_4	3.7	30.8	32.4	34.5	28.5	23.8
C_2H_2	0.2	0.3	0.4	0.9	–	–
C_2H_4	30.9	24.0	28.8	28.5	26.9	5.5
C_2H_6	27.1	3.9	6.0	8.6	7.9	16.6
C_3H_6		11.1	14.9	14.1	14.0	9.6
C_3H_8		11.3	0.5	0.6	1.2	14.8
C_4H_8	1.4	0.9	1.7	0.4	2.1	
C_4H_8		0.7	1.1	0.7	5.9	1.0
C_4H_{10}		0.1	4.8	0.7	0.3	
C_5+		0.8	1.0	0.5	–	–
	100.0	100.0	100.0	100.0	100.0	100.0
CH_4/H_2 ratio	0.10	1.92	3.86	3.29	2.16	–

*Includes 15% N_2 and CO

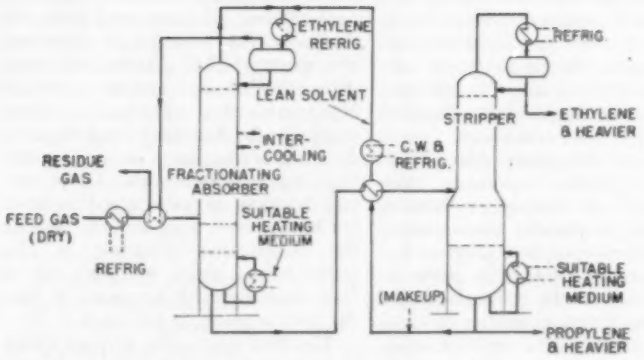

Figure 3. Demethanization by C_2 absorption-stripping

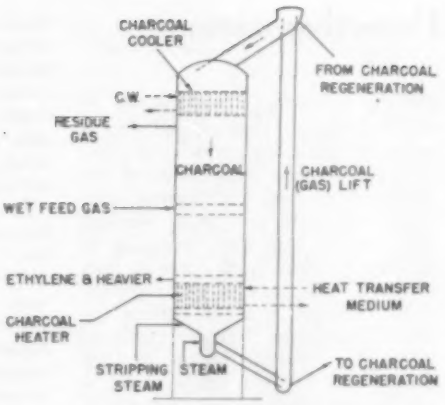

Figure 4. Demethanization by Hypersorption

tion is used. An excellent description of an over-all ethylene recovery system employing such a demethanization method is given by Pratt and Foskett *(13)*.

2. *Operation at 100-150 lb./sq. in. abs.* The description of the demethanization operation at 100-150 lb./sq. in. abs. is quite similar to that given for the higher pressure level. Temperatures are lower, with the feed being cooled to −150°F. and the head temperature running as low as −200 to −210°F. Evaporating methane refrigerant is used to condense reflux for the column. Further details may be found in the paper by King and Warburton *(9)*.

3. *Operation at 30-40 lb./sq. in. abs.* In contrast to operation at the higher pressures, demethanization at 30-40 lb./sq. in. abs. may be effected without the use of external refrigeration. Design is along the lines of air separation units, with extensive heat exchange and gas expansion being used to approach a high thermodynamic efficiency.

Feed gas is compressed to 250-300 lb./sq. in. abs., after which it is cooled, dehydrated by means of a solid desiccant, and passed to an insulated cold-box. Major low-temperature processing items are contained in this cold box, and include fractionation equipment for separating ethylene from the demethanizer bottoms.

Reversing-type exchangers are used to chill the feed gas by heat transfer to all of the outgoing gas streams from the separation unit. Final refrigeration to −250°F. is obtained by Joule-Thomson expansion, and demethanization takes place in a conventional bubble-tray unit. Phase equilibria are such that only a stripping zone is required, and reboil vapors are produced by heat transfer from condensing ethylene.

Details of this process have not been published. However, the reader will find some information of interest in the paper by Schutt and Zdonik *(14)*, and in an article describing a Canadian plant which uses the process *(1)*.

Absorption-Stripping. This method of demethanization involves the removal of ethylene and heavier components from the feed gas by means of a selective solvent. Methane and lighter components remain in the gaseous phase and are discharged from the system. The recovered components are stripped from the solvent, which is then recirculated. The solvent may be one of the heavier components of the feed gas, or it may be an extraneous material chosen for its absorptive power and its selectivity between methane and ethylene. Two solvents have found commercial use in this country: an aromatic distillate, of 75-85 mol. wt.; and a propane-propylene fraction. Both of these solvents are contained in the effluent from the pyrolysis of propane and heavier materials and are therefore convenient to use. The demethanization systems which employ them are distinctly different, however, and are best described separately. The range of operating conditions so covered includes those for systems which might employ alternate solvents.

1. *Aromatic Absorption.* A flow diagram for this method is given in Figure 2. All processing steps are directly comparable to refinery and natural gasoline absorption-stripping practice. Of greatest interest is the solvent, which may in fact vary considerably in composition, depending upon feedstock and pyrolysis conditions. A highly aromatic solvent, as described by Kniel and Slager *(10)*, forms the basis for this discussion. However, the aromatic content may be less than 50% *(6)*, and if ethane pyrolysis is used an extraneous solvent of controlled aromatic content may be necessary. In some cases a material such as normal hexane may be specified as a solvent, but in the course of operation aromatics in the feed gas tend to build up in the circulating oil.

Economics dictate an operating pressure level of 450-500 lb./sq. in. abs. in the absorber, with lower pressures in the stripper limited by the coolant requirements for condensing reflux. Minimum operating temperatures of 0-30°F. are set by the crystallizing point of the solvent. Maximum temperatures of 400-450°F. in the stripper are set by the tendencies for unsaturated hydrocarbons to polymerize and give fouling problems.

Compressed feed gas, from which the majority of C_3 and heavier components have been removed, is fed directly to the fractionating absorber. (If subfreezing temperatures are used in the absorber or stripper, chilling and dehydration of the feed gas is also required.) In the absorption zone, ethylene and heavier materials pass into the liquid phase, with methane and lighter materials passing out as overhead gas. Fresh solvent is chilled to 0-30°F., and is heated to 20-100°F. at the feed tray, depending upon circulation rate, degree of absorption, and whether intercooling is used in the absorber. The feed tray temperature-pressure conditions are important in that they fix the minimum solvent circulation requirement.

Methane unavoidably dissolved in the solvent is removed in a stripping zone below the absorber. A separate column may be used for this residual demethanization if independence of pressure-temperature conditions is desired. The solvent is heated to 200-

continued on next page

Demethanization

250°F., depending upon degree of methane removal desired, and then is fed to the main stripper wherein ethylene and heavier components of the demethanizer feed are removed overhead. Alternate processing methods may utilize stagewise stripping in which a C_2 fraction is removed first, followed by C_2 and heavier rejection.

The stripper is a conventional refluxed fractionator. The pressure level is in the 300-450 lb./sq. in. abs. range, and bottoms temperatures at the higher pressures are 400-450°F. Some polymerization of C_4+ unsaturates occurs, resulting in heavy oils which must be removed. Inhibitors may be used to suppress this polymerization (6).

Table 2. Cost of Refrigeration
Relative to --30°F. Level

Level °F.	Refrigerant	Investment cost	Operating cost
+30	Propane	0.56	0.68
0	Propane	0.73	0.82
—30	Propane	1.00	1.00
--60	Ethane	1.47	1.68
—90	Ethane	1.72	1.82
—120	Ethylene	2.42	2.25
—150	Ethylene	3.10	2.64

Note: Data based on 5,000,000 B.t.u./hr. total capacity of refrigeration system. Relative costs per unit of heat removed.

Table 3.
Demethanizer Feed Pretreatment

Process	Lb./sq.in.abs.	Dehydration	C_4 Removal
Fractionation	450-600	Yes	No
	100-150	Yes	No
	30-40	Yes	No
Absorption	C_3 solvent	Yes	Yes
	Aromatic solvent	No*	No
Adsorption		No	Yes

**Dehydration required if hydrate formation likely in stripper reflux condensation.*

Table 4. Absorption Oil produced by light Hydrocarbon Pyrolysis
150-300°F. Boiling Range

Charge to pyrolysis	Wt. %	% Aromatics
Ethane	0.7	50-60
Propane	3.4	50-60
65% propane, 35% propylene	12.1	60-70
70% propane, 21% propylene, 9% ethane	6.4	60-70
n-Butane	9.8	65-75

Note: Wt-% refers to pyrolysis charge. Conversion levels are those commonly used commercially.

Detailed process descriptions for the aromatic absorption-stripping demethanization method have been published (2, 10). It should be emphasized again that a range of solvent characteristics may be encountered within a single plant, depending upon pyrolysis conditions.

2. *Propane-Propylene Absorption.* Propane-propylene represents the lower limit of solvent molecular weight used in ethylene recovery systems. A generalized flow diagram for a C_3 absorption system is given in Figure 3. Obviously, if the feed gas contains significant quantities of C_4+ materials, they must be removed separately or be allowed to concentrate in the circulating oil. In this discussion it will be assumed that a solvent consisting essentially of C_3's can be maintained.

To prevent excessive solvent losses, it is necessary to maintain the absorber top temperature in the vicinity of —100°F; thus, as in the case of straight fractionation, design problems are centered around low-temperature-processing requirements. The feed must be carefully dehydrated and chilled to 0°F. or below. Refrigerated intercooling must be used in the absorption section, and alloy steels are necessary for low-temperature environments. The absorber operating pressure is 450-500 lb./sq. in. abs.

The lean solvent is chilled to —100°F. or below, with evaporating ethylene refrigerant required in the final cooler. This cooler serves also to recover solvent from the off-gas and ensure equilibrium at the top of the absorber. Further recovery of condensables from the off-gas may be obtained by adiabatic or isentropic expansion.

Residual methane is stripped in the lower section of the fractionating absorber, with bottoms temperatures of 50-100°F., depending upon degree of stripping desired. The rich solvent then passes to a conventional stripper, which separates between C_2 and C_2+ components. As a unit, this demethanization system produces three fractions instead of the usual two.

Selective Adsorption. Demethanization by selective adsorption may be practiced under license using the Hypersorption process of Union Oil Company of California (5, 8) or the Fluid Char process of Esso Research and Engineering Company (3). Only Hypersorption is used commercially and the discussion here will be restricted to this process. However, the principles involved are quite similar for the two processes.

Hypersorption demethanization is based on the large selectivity between methane and ethylene over activated charcoal. The feed gas is contacted by a moving bed of charcoal adsorbent with ethylene and heavier materials being removed as adsorbate and later stripped. By control of stripping conditions it is possible to remove C_2 and C_2+ fractions separately (5) but certain features of this operation have not been proved commercially, and for the comparative purposes of this paper only a single stripping cut of C_2+ materials will be used. A flow diagram is given in Figure 4.

The feed gas to the Hypersorption unit must be pretreated for the removal of all C_4 and heavier hydrocarbons. Unsaturated C_4's tend to adsorb irreversibly on the charcoal. The adsorber column operates at 75-150 lb./sq. in. abs. and receives compressed gas at a central point. Methane and lighter components are essentially unadsorbed and pass off through the overhead vapor line. Adsorbed ethylene and heavier components are removed by stripping steam and elevated temperature, and pass off through a side drawoff to final ethylene purification.

Stripped adsorbent is recirculated by means of a gas lift. Some irreversible adsorption occurs, which requires continuous withdrawal of a small portion of adsorbent to a high-temperature regenerator. Details of the Hypersorption process may be found in the article by Berg (5).

Process comparisons

As stated previously in this article, the final choice of a demethanization design must be based on the unique requirements at hand. These requirements encompass the entire ethylene manufacturing scheme, and the optimum solution will depend on desired

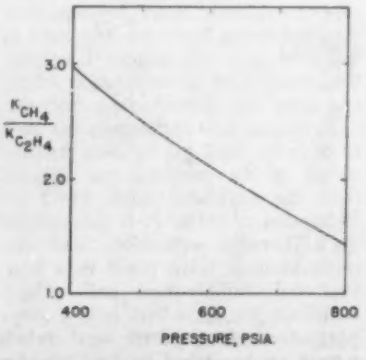

Figure 6. Relative volatility, methane-ethylene (high-temperature region)

flexibility, limitations on capital expenditures, and minimum allowable return on investment. It is difficult, if not impossible, logically to compare demethanization methods without reference to other parts of the over-all process. Thus, the remarks here will be kept on a general basis, at least as they refer to economics.

The following criteria are important in the selection of a demethanization method:

1. Selectivity
2. Separation efficiency
3. Ethylene recovery
4. Energy requirements
5. Feed pretreatment
6. Chemicals and by-products
7. Operating flexibility

Selectivity. Selectivity between methane and ethylene is of importance in establishing theoretical stage requirements for the demethanization separation. For distillation and absorption, selectivity is expressed as the *relative volatility*, α:

$$\alpha = K_{CH_4} / K_{C_2H_4}$$

where K is the familiar vapor-liquid equilibrium ratio ("K value"). For adsorption, relative volatility may be defined on an analogous basis:

$$\alpha' = \frac{Y_{CH_4}/N_{CH_4}}{Y_{C_2H_4}/N_{C_2H_4}} = K'_{CH_4}/_{C_2H_4}$$

where Y = mole fraction of component in vapor

N = wt. component adsorbed/wt. adsorbent

For straight fractionation, relative volatility values are given in Figures 5 and 6. The values are based on the hydrogen-methane-ethylene ternary data of Likhter and Tikhonovich *(12)* for the low-temperature region and K values from the Kellogg charts *(7)* for the high-temperature region. These figures are intended to be illustrative, and other sources of equilibrium data are available. The paper by Benham, Katz, and Williams *(4)* provides a list of references on the subject. It may be noted, however, that the data of Figures 5 and 6 have been confirmed in plant operation.

For absorption demethanization, great care must be exercised in the selection of equilibrium data. For aliphatic-type solvents the Kellogg K values *(7)* are appropriate. For aromatic solvents the Kellogg values may be corrected by the method of Solomon *(15)* which is reproduced graphically in Figure 7. On the basis of these methods, relative volatility values for three solvents have been computed and are given in Figure 8.

For adsorption, relative volatility values can vary considerably with small changes in character of the adsorbent. Hypersorption development work was based on a gas mask grade charcoal. For material of this type (Columbia G), Lewis *et al. (11)* report a relative volatility of 15.4 at 25°C. and 1.0 atm. Pressure-temperature effects on this volatility have not been reported, but the value is known to be somewhat lower under conditions of Hypersorber operation.

Separation Efficiency. Stage efficiencies for fractionation demethanization are about 50-60%; for absorption demethanization they are 30-50%, with the higher values for the lower molecular weight solvents. For charcoal adsorption, the height equivalent to a theoretical stage is in the range of 1-2 ft., depending on size and circulation rate. Demethanizer fractionators and fractionating absorbers usually run 30-50 actual trays.

Solvent circulation rate may be included under separation efficiency. Relative rates for three solvents are shown in Figure 9 for illustrative purposes. The marked variation should be noticed, but quantitative deductions obviously cannot be made from such a chart. The apparent advantage of the C_3 solvent arises from its low molecular weight and high selectivity at the lower temperatures.

Ethylene Recovery. With sufficient solvent circulation and contacting trays, the absorption-stripping systems may be designed for 99% or better ethylene recovery. Similarly, with sufficient adsorbent circulation and contacting height the selective adsorption processes can recover essentially all of the ethylene in the feed gas. Operating experience with the aromatic absorption-stripping system shows, for example, an ethylene recovery of 98.5% with forty actual trays in the fractionating absorber.

Practical limitations may be imposed on the recovery using straight fractionation, however. To demonstrate these, the high pressure (450-600 lb./sq. in. abs.) demethanization process will be used. Since operating temperatures lower than −150°F. are not feasible, some ethylene must be lost with the off-gas if reflux is to be condensed for the demethanizer. The amount of this material depends upon pressure also, but 600 lb./sq. in. abs. has been found to be about maximum from over-all plant considerations. Figure 10, based on the data of Likhter and Tikhonovich *(12)*, shows the equilibrium concentration of ethylene in the off-gas at −139°F. On the basis of the feed stream data of Table 1, one may calculate that for ethane pyrolysis a maximum recovery is 90% at 588 lb./sq. in. abs. and 89% at 440 lb./sq. in. abs. Similarly, for propane pyrolysis the recoveries are 95 and 92% respectively. In the case of ethane pyrolysis there is sufficient ethane present in the off-gas effectively to improve the ethylene recovery to 93-95%. The conclusion is, how-

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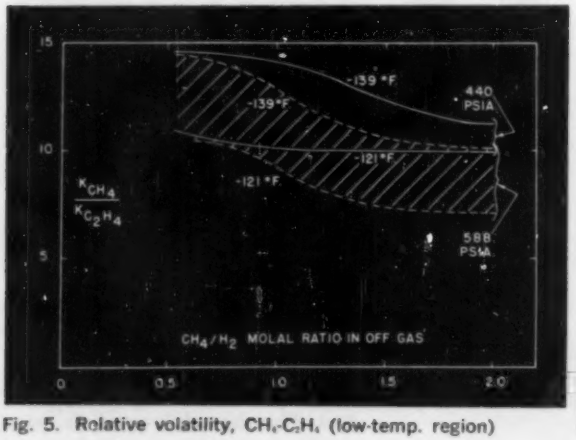

Fig. 5. Relative volatility, CH_4-C_2H_4 (low-temp. region)

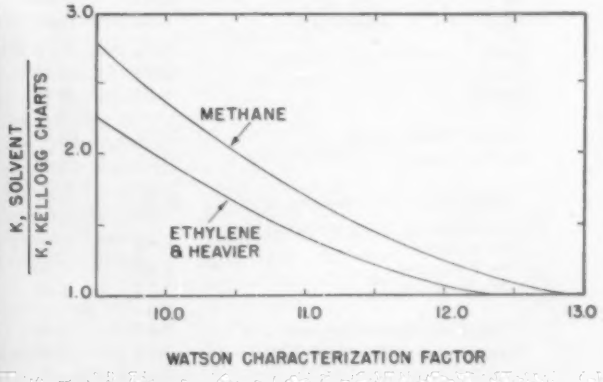

Figure 7. Solvent aromacity correction to Kellogg K values (15)

Demethanization

ever, that a 95% ethylene recovery is about maximum with low temperature straight fractionation.

Auxiliary equipment may be used to increase the recovery of ethylene from the fractionator off-gas. In one case a Hypersorption unit is used (8). Other cases employ an adiabatic expansion to lower the gas temperature. Isentropic expansion through a turbine, providing off-gas temperatures of −200°F. or below, may be used to recover additional ethylene and also supplement the refrigeration system through heat exchange. Figure 11 shows the reduction in ethylene loss possible by lowering the temperature.

Energy Requirements. Principal energy requirements for demethanization fall into three categories:

1. Feed gas compression
2. Refrigeration
3. C_2 + stripping

Other requirements include residual methane stripping and solvent (or adsorbent) circulation.

The application and balancing of these categories not only are unique for each design problem, but also are subject to the judgment and experience of the designer. Desirably, some means should be available for comparing costs of energy at various levels of addition or removal. In some cases the comparisons are made semiquantitatively, with two or three "best" process schemes then being subjected to detailed cost studies.

Although the subject of feed gas compression does not fall within the scope of this paper, it must be given some consideration in determining the optimum demethanization scheme. For straight fractionation, reduced feed gas compression results in increased refrigerant compression. For absorption-stripping, savings in feed gas compression are likely to be offset by increased solvent circulation rates and equipment sizes. For selective adsorption, operating pressure level is limited by stripping requirements and adsorbent temperatures. Most demethanization is carried out in the vicinity of 500 lb./sq. in. abs. and for this level about 0.7-1.0 bhp./lb./ ethylene recovered is required.

For the C_2 absorption and straight fractionation systems, the major energy requirements are for heat removal. Table 2 shows the relative cost for heat removal as a function of temperature level. In a typical case of straight fractionation about 40% of the refrigeration load is at levels below −100°F. The table shows, for example, that at −120°F., heat removal costs 2.42 times as much in operating cost, and 2.25 times as much in investment cost, as heat removal at −30°F. By use of the factors shown in Table 2, the equivalent refrigeration duty for fractionation is on the order of 700-900 B.t.u./lb. ethylene recovered, at a −30°F. level. C_3 absorption process refrigeration requirements are of the same magnitude. However, for high temperature aromatic absorption-stripping, the refrigeration duty (for chilling the lean solvent) is about 400 B.t.u./lb. ethylene at the equivalent −30°F. level. Energy for C_2+ stripping is significant in the aromatic absorption-stripping and selective adsorption methods. Requirements run on the order of 4000 B.t.u./lb. ethylene recovered, and in some cases, direct-firing or use of heat transfer media are necessary.

Feed Pretreatment. Pretreatment of the demethanizer feed involves the removal of the C_4 and C_5 hydrocarbons, and the removal of water. The necessity and cost of these operations obviously affect the choice of a demethanization method. Table 3 summarizes pretreatment requirements for the methods described in this article.

Chemicals and By-products. The residual gas from demethanization is a common by-product to all processes. In addition, the aromatic absorption system produces a heavy oil (200-550°F. B.R.) of aromatic character which is produced in the high temperature zone of the stripper. A separate column must be used to remove this oil from a sidestream of the circulating solvent. Although it must be replaced by fresh solvent, it has a value about equal to that of the solvent.

Chemical consumption by the adsorption and absorption processes may be considerable. For Hypersorption there is a continuous loss of charcoal due to attrition and, in some cases, to rejected material of lowered activity. This loss can represent as much as 0.1¢/lb. on product ethylene, in addition to the cost of storage and handling.

For the absorption systems there is the problem of solvent make-up. If the aromatic system is used, the solvent may be supplied through the feed gas. Table 4 shows the production of aromatic oil from the pyrolysis operation. Some of this oil is removed in the feed gas compression system, and it may be stated roughly that about 2.5-3.0 wt.% oil in the pyrolysis gas is required to make up the losses due to vaporization and to conversion to heavy oil in the circulation system. Thus, propane pyrolysis can barely supply solvent requirements, while ethane pyrolysis definitely cannot.

The volatility of the propane-propylene solvent for the C_3 absorption-stripping system is such that solvent losses in the residual gas are inevitable. Thus, for a feed gas from ethane pyrolysis (Table 1) it is necessary to provide make-up solvent facilities. For the other pyrolysis gases

Table 5. Cost Comparison of Ethylene Plants
Bases: 120,000,000 lb./yr. C_2H_4 at 95% purity
Gulf Coast Location

Capital cost, $, million	Propane absorption-fractionation	Aromatic absorption-fractionation	Straight fractionation*	Hypersorption
Pyrolysis section	1.71	1.71	1.71	1.71
Recovery section	10.32	11.95	11.08	10.56
Backup (non-mfg.)	1.19	1.46	1.03	0.96
Total fixed capital	13.22	15.12	13.82	13.23
Working capital	0.09	0.09	0.09	0.13
Total fixed and working capital	13.31	15.21	13.91	13.36
Manufacturing cost, ¢/lb. C_2H_4				
Raw materials	0.74	0.74	0.74	0.86
Direct expense	1.03	1.20	1.03	1.04
Indirect expense	1.30	1.45	1.37	1.32
Total manufacturing cost	3.07	3.39	3.14	3.22
Return on investment at 20%	2.10	2.52	2.30	2.21
Comparative mfg. cost	5.17	5.91	5.44	5.43

*500 lb./sq.in. abs. pressure level

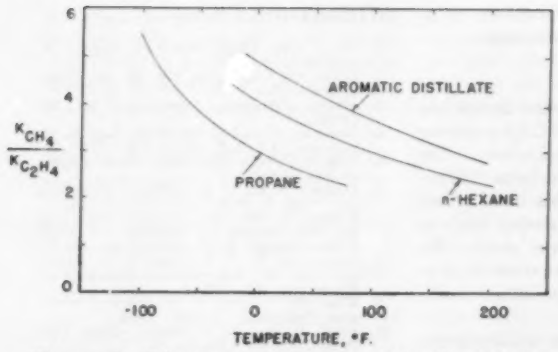

Figure 8. Solvent selectivity (for absorption-stripping demethanization at 500 lb./sq. in. abs.)

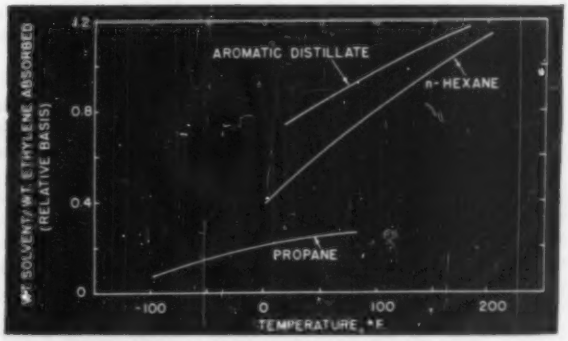

Figure 9. Relative solvent circulation rates (for absorption-stripping demethanization at 500 lb./sq. in. abs.)

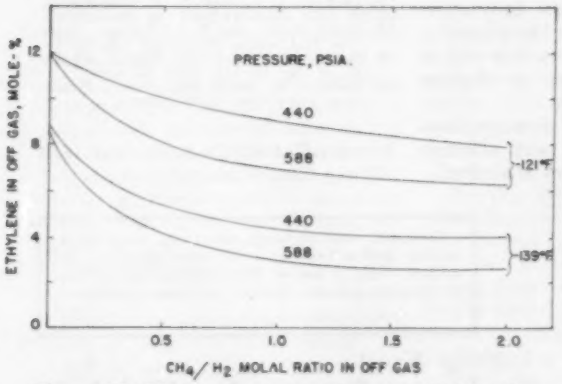

Figure 10. Ethylene losses in off-gas (straight fractionation process)

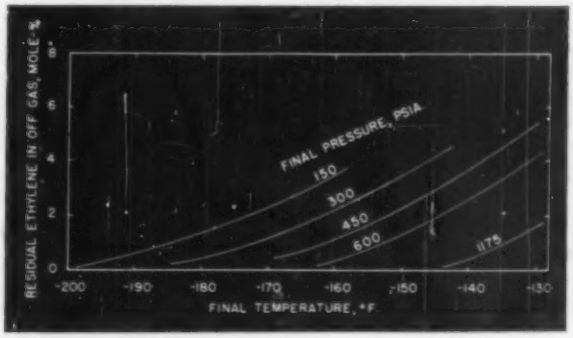

Figure 11. Expansion and cooling of demethanizer off-gas Basis: feed gas from demethanizer: hydrogen, 31 mole %; methane, 63 mole %; ethylene, 6 mole % = 100 mole %

the solvent normally is supplied in the feed gas.

Operating Flexibility. Flexibility of demethanizer operation may be related to (a) variations in feed gas composition due to adjustments in pyrolysis operations, and (b) feedback control aspects of low-level refrigeration recovery.

If wide variations in ethylene content of the feed gas are anticipated, it is likely that absorption-type processes will be superior to the fractionation type. Ethylene recovery limitations of fractionation have been mentioned previously, but in addition the required spread of plates-reflux requirements can mean that optimum operation occurs only infrequently. On the other hand, absorption processes may be designed for economic operation over a range of ethylene concentrations in the feed. Claims have been made that adsorption possesses the same flexibility for feed composition as absorption, but confirmation of the claims has not been made available.

An important consideration in demethanizer design is the controllability of the system. For low-temperature absorption or fractionation, the designer tends to "squeeze" all possible heat recovery from the system by exchange between in-process streams. This is particularly the case for the low-pressure (30-40 lb./sq. in. abs.) fractionation units where heat leaks assume the same importance as in air-separation plants. Unfortunately, such economies can lead to control problems, and instability during start-up and operation with transient disturbances are regularly experienced. Present trends in the design of control systems undoubtedly will lead to better performance of low-temperature separation plants.

Demethanization economics

The economics of the demethanization step are inextricably bound to the other processing steps of the ethylene recovery system. The effects of recycle streams, process heat recovery, common utilities, etc., make economic comparisons of the isolated demethanization step of little practical value. The discussion here must of necessity include the over-all ethylene recovery system.

Ultimately, demethanization methods must be compared as parts of alternate methods for manufacturing ethylene, based on a particular feedstock material. Such a course of action will be described here, being based on the production of 120,000,000 lb./yr. of 95% ethylene at a Gulf Coast location. The feedstock for this plant is a refinery gas, containing about 7 mole % ethylene, which is charged to the recovery system. Recovered ethane and propane-propylene are recycled to pyrolysis units, the effluent from which is combined with the fresh refinery gas charge. Ethylene from pyrolysis represents about 75% of the total production.

Detailed process design and cost estimating studies were made, using the four major demethanization methods described earlier in this paper:

1. Propane absorption-stripping
2. Aromatic absorption-stripping
3. Straight fractionation (500 lb./sq. in. abs.)
4. Hypersorption

Identical pyrolysis facilities were used for each case. Conventional facilities were used for gas compression, gas dehydration, and C_2-C_4 separation. Also included in the designs were facilities for removing carbon dioxide and hydrogen sulfide from the refinery gas.

Results of these studies are summarized in Table 5. Including return

continued on next page

Ethylene purification

continued

on investment, the transfer price for ethylene is shown to be in the 5-6¢/lb. range. Total invested capital is in the range of $13-15 million, and of the latter some 75-80% is represented by recovery facilities. In turn, a significant portion of recovery capital is directly associated with demethanization.

For the particular set of circumstances used, the C_2 absorption-stripping method appears to be advantageous. Capital investment is slightly lower, and manufacturing cost considerably lower, than the other three methods. Actually, only the aromatic absorption-fractionation system shows a distinct disadvantage, with the choice between the other three likely to be based on such noneconomic factors as status of basic technology, flexibility for varying feedstock composition, and ease of operation.

Conclusions

The trend in the United States has been along the lines of high-pressure fractionation demethanization. The experience gained has been instrumental in continuing this trend. Also, comparative economic studies such as those reported here have shown the high-pressure fractionation method to be competitive with the other methods.

The authors feel that low-temperature absorption and low-pressure fractionation deserve more attention than is usually accorded them. In particular, the former appears to possess a combination of attributes that will fit a great many premises of ethylene recovery plant design.

As basic technology develops, low-pressure fractionation and selective adsorption may be more attractive.

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Presented at A.I.Ch.E. Meeting, Salt Lake City, Utah.

Low-temperature demethanization *...the advantages*

Comments reporting recent commercial discussion regarding preferential means of demethanization, and reasoning relating thereto, were requested of Mr. Kniel of Lummus and Mr. McGarry of Stone & Webster. —Editor

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The Lummus Company, New York, N. Y.

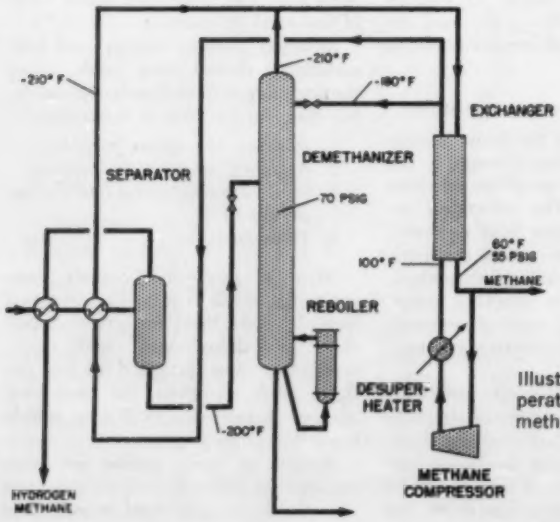
THE PAST three or four years have seen unprecedented growth of polyethylene and polypropylene production with exacting demand for a highly pure product.

It would seem that the presently established demand for 99.9 mol% pure ethylene would require modification of, or additions to, a low temperature as well as to an absorption type of plant considered on the basis of acceptable design standards of as recently as 1954 *(1)*.

Today, the low temperature route, if properly designed, is not at a disadvantage compared to the absorption route, although this may have been true five or ten years ago.

It is now indeed possible to effect a recovery of 98 or more percent of the ethylene going to the demethanizer of a cold plant by the judicious use of methane refrigeration. It would seem that designers have shown reluctance to employ methane refrigeration for demethanization. To obtain some idea of the magnitude of the savings resulting from higher recovery, assume it were possible to increase the recovery of a conventional demethanizer from 93 to 98% or by 5.4% in a plant with a yearly production of 120 million pounds of the 99.9 percent pure grade. The extra 6.5 million pounds at 6.15 cents per pound over fuel would have a value of $400,000 and an expenditure in the order of $800,000 would be justified to achieve this extra production. Studies show that with this higher recovery, a much higher purity would be realized, without extra cost, so that further means, such as an extra tower to obtain the 99.9 percent purity, could be dispensed with.

The keys to the improved low temperature recovery process are lower pressure and adequate reflux. The demethanizer would be operated as shown in the accompanying illustration, approximately for a ratio of 0.8 mols of methane per mol of ethylene (0.46 pounds per pound) entering in



Illustrating the low temperature route to demethanization

the feed. Referred to overhead, the internal reflux required is of the order of 0.75: 1.0 with a tower pressure between 60 and 70 lb./sq. in. gauge, the fuel gas pressure being 40 lb./sq. in. gauge. If care is taken to eliminate most of the hydrogen over a precondensation stage, the resultant overhead temperature would be −210°F. and the ethylene loss less than 1% of that entering in the feed.

For a ratio of methane to ethylene in the feed of 0.8 mols/mol the reflux would remove slightly over 70 B.t.u. per pound of ethylene. The expansion across a nozzle by comparison of the overhead from a demethanizer operating at 450 lb./sq. in. gauge down to a pressure of 60 lb./sq. in. gauge would yield by subsequent reheating only 37 B.t.u. per pound of methane or 17 B.t.u. per pound of ethylene at the ratio of 0.8 mols per mol methane to ethylene. But the reflux requirements at a pressure of 450 lb./sq. in. gauge would of course be substantially higher than 70 B.t.u. per pound of ethylene produced.

The 17 B.t.u. per pound effect holds for pure methane. If the overhead consists of hydrogen and methane, the effect is relatively more feeble at −140°F, which is not much below −100°F, the inversion temperature for hydrogen, above which expansion is accompanied with a temperature increase.

It is due to this difference in requirements and availability that the expansion effect cannot be used to produce reflux. It is generally used to cool the net overhead flow from the demethanizer as much as possible to obtain a fractionally better recovery of ethylene.

The reversible work of the liquefaction of one pound of methane at −210°F may be easily calculated as 285 B.t.u. which incidentally about equals that for one pound of liquid air at atmospheric pressure. This makes 0.75 x 0.46 x 285 equal to practically 100 B.t.u. per pound of ethylene produced. On account of inherent irreversibilities in the methane cycle—particularly the losses through adiabatic instead of isothermal compression—expansion across a valve, and the finite temperature differences across exchangers, the actual work to produce this refrigeration is about twice as large, or 200 B.t.u. per pound of ethylene.

For the 120 million pound per year plant the methane compressor would thus require 15,000 x 200 x 1/2547 = 1180 brake horsepower. In one design there would have to be added to this figure 15% for refrigeration to one other exchanger and 2% for heat losses, making the total 1380 bhp.

It follows that the entire methane system could be built for less than one year's savings in recovery with no credit applied toward the attainment of a much higher purity.

Low temperature absorption, by means of propylene or a mixture of propylene and propane, has been described *(1)* as possessing attractive features if the solvent loss can be kept low. I am able to report findings from a recent plant start-up involving the production of 98-plus percent purity ethylene in a plant using naphtha or a light gasoline as charge stock. The recovery there exceeded 99 percent; the solvent loss, propylene, was of the order of 3 percent of the amount of propylene entering which was less than 1.0 percent referred to circulation.

A solvent temperature of −100°F has been proposed *(1)*. I cannot see an advantage of such low temperatures unless the remainder of the plant is operated differently from usual. The solvent recovery problem is unquestionably one of the disadvantages of the absorption process; special measures must be taken to keep the loss within tolerable limits.

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30 decisions favoring *low-temperature* demethanization

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The bulk of ethylene plant capital and operating costs are associated with recovery and purification of the ethylene; the cost of the purification system employed is closely related to the demethanization method selected. Virtually all ethylene producers whose plants have been constructed or expanded within the past 15 years have examined alternatives or made comparisons between low temperature fractionation at about 500 lb./sq. in gauge versus absorption-stripping in a selective solvent. That the subject was of importance as early as 1947 is illustrated by the remarks of M. Souders *(1)* commenting on the absorption plant described by Kniel & Slager *(2)* and comparing it to the low temperature fractionation system described by Pratt & Foskett *(3)*.

In the course of designing about 30 commercial ethylene plants, Stone & Webster Engineering Corp. has repeatedly compared low temperature fractionation versus absorption-stripping. Although the majority of these comparisons have been executed as new plant design studies, with estimated costs, they have been based on return cost analyses and commercial scale operating data from both low temperature fractionation and absorption-stripping installations. We do not feel it is appropriate to present comparative figures derived from these studies, because the details required to provide meaningful support are voluminous and also vary considerably from case to case. In a vast majority of cases, however, these comparisons have favored low temperature fractionation, and that is the system employed in nearly all of the plants that we have built.

We expect that this trend toward low temperature fractionation will continue.

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ethylene purification

Acetylene removal from polyethylene grade ethylene

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THE DEMAND for ethylene for the production of petrochemicals has increased greatly since World War II and more especially since 1950. Most of the increased production of ethylene comes from refinery off-gases and hydrocarbon cracking of ethane, propane, butane and naphthas. The ethylene thus produced contains varying amounts of acetylene and acetylenic compounds depending on the hydrocarbon being cracked and the cracking conditions. The acetylene content will vary from 1-2% to a few tenths percent.

The presence of acetylene in the ethylene affects both the catalyst life in the petrochemical process and the quality of the petrochemical produced. Although the degree of removal of acetylene required is determined by the ultimate application of the ethylene, generally removal to less than 100 p.p.m. of acetylene is required, and most of the ethylene now being marketed will have the acetylene reduced to less than 20 p.p.m. and some as low as 10 p.p.m.

Although appreciable quantities of acetylene are removed from the ethylene during the normal fractionation process, additional removal is usually required. Depending on the fractionation process, as much as 50 to 75% of the acetylene is sometimes removed during fractionation.

Acetylene removal from ethylene is accomplished through two principal processes: solvent extraction and selective hydrogenation. Most of the ethylene now being produced is purified by selective hydrogenation. This paper describes the principal selective hydrogenation processes used in this country for the removal of acetylene.

Figure 1 shows the steps in one of several typical schemes for the recovery and purification of ethylene with the selective hydrogenation of acetylene omitted *(1)*. In this scheme, and depending on the source of ethylene, the gas is compressed to 50-100 lb./sq. in. gauge and the aromatic distillate removed. After further compression and carbon dioxide removal, the gas is dried at approximately 400-500 lb./sq. in. gauge. It is then subjected to an absorption step at a low temperature where hydrogen and most of the methane are separated. The bottoms from the absorber goes to the deethanizer where, at a higher temperature, an overhead fraction, consisting of 60-80% ethylene and the remainder mostly ethane, is taken off. The bottoms from the deethanizer consists of a C_2-C_4 fraction. The overhead from the deethanizer goes to an ethylene fractionator. The overhead from this tower is a low purity ethylene containing 1-2% methane. This may be subjected to further purification by fractionation to produce an ethylene having a purity of 99+ and available at about 300-500 lb./sq. in. gauge.

Acetylene removal by selective hydrogenation may be accomplished at any one of several points during the recovery and purification of the ethylene.

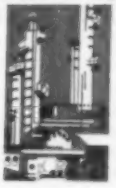
1. It may be removed after any one of the stages of compression but after separation of the aromatic distillate and before drying the gas.
2. It may be removed after the dryer but prior to refrigeration.
3. It may be removed from the feed to the first ethylene fractionator.
4. It may be removed from the feed to the second fractionator.
5. It may be removed from the high purity product ethylene.

Removal at each of these points offers certain advantages and disadvantages.

Removal of the acetylene ahead of the dryers has the principal advantage that the hydrogen needed for the hydrogenation is available in the feed. However, since the quantity of hydrogen available is not only sufficient to hydrogenate the acetylene but also much of the other olefinic materials present, the hydrogenation must be conducted under conditions and with a catalyst whereby only insignificant quantities, especially of ethylene, will be hydrogenated. This requires a special catalyst which is highly selective in promoting the hydrogenation of the acetylenic linkages. Certain operating conditions influence the selectivity of the catalyst. The presence of relatively small quantities of sulfur compounds or carbon monoxide generally enhances the selectivity of the catalyst. Too high a concentration of sulfur will reduce the activity of most catalysts and interfere with the removal of the acetylene.

Since the addition of steam usually improves the selectivity and reduces the fouling of the catalyst by polymer formation, steam may be added without increasing the load on the dryers. Hydrogenation of the acetylene ahead of the dryers and ahead of the acid-gas-removal system has the further advantage that certain highly unsaturated hydrocarbons and oxygen, sometimes present in trace quantities, are removed by hydrogenation and, therefore, fouling of the carbon dioxide removal system may be avoided. If the gas stream contains appreciable quantities of hydrogen sulfide, hydrogenation may be placed after carbon dioxide removal, thus decreasing the quantity of sulfur coming in contact with the catalyst. Removal of acetylene at this point has the disadvantage that the volume of gas to be treated is relatively large and, therefore, the quantity of catalyst may be larger than if the acetylene were removed at subsequent points in the purification. Any tars or polymers being carried by the gas stream may collect on the catalyst, thereby requiring more frequent regeneration of the catalyst. The catalysts most commonly used for promoting the hydrogenation of the acetylene at this point in the system are the cobalt molybdate and nickel base catalysts. Most of the ethylene now being produced commercially involves acetylene removal at this point in the purification system.

Removal of the acetylene after the dryer but ahead of refrigeration has the advantage that hydrogen is available in the gas for the hydrogenation of the acetylene. The pressure, usually being higher, would permit higher space velocities during hydrogenation and result in the use of smaller reactors and less catalyst. This point in the purification system has the disadvantage that steam cannot be added to control selectivity and reduce fouling of the catalyst without requiring additional drying capacity. Due to the higher pressure, a high degree of selectivity is more difficult to attain and the ethylene losses due



to hydrogenation of ethylene to ethane may be somewhat greater. To our knowledge, there are no commercial installations where the acetylene is being removed at this point.

Removal of the acetylene from the feed to the first ethylene fractionator has the advantage that generally it is necessary to treat less than 40% of the gas in either of the preceding stages. This may result in the use of a smaller reactor and less catalyst. Since the gas would contain fewer tars and polymers, less frequent regeneration of the catalyst would be required. Selectivity is then attained by controlling the quantity of hydrogen added. Catalysts used for hydrogenation of the acetylene at this point would generally be the rare metal catalysts which are not only more expensive but are quite sensitive to poisoning from the sulfur that may be present in the gas stream. Any polymers formed during hydrogenation of the acetylene and any residual hydrogen would be removed from the ethylene during the subsequent fractionations.

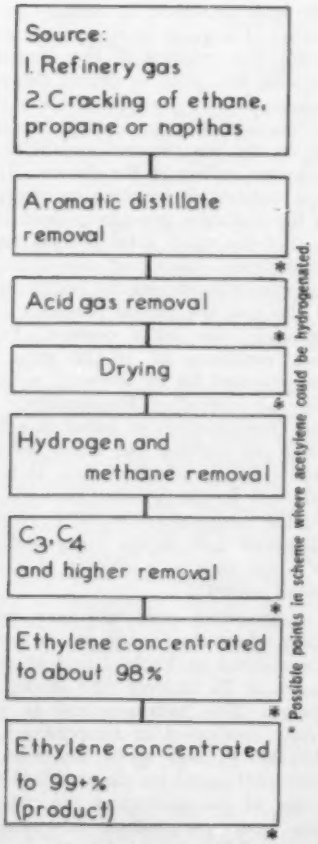

Source:
1. Refinery gas
2. Cracking of ethane, propane or napthas
Aromatic distillate removal
Acid gas removal
Drying
Hydrogen and methane removal
C_3, C_4 and higher removal
Ethylene concentrated to about 98%
Ethylene concentrated to 99+% (product)
* Possible points in scheme where acetylene could be hydrogenated.

Figure 1. Typical scheme for the recovery of ethylene.

Acetylene removal at this point has the obvious disadvantage that the hydrogen must be supplied from some external source; however, a source of impure hydrogen is usually available that can be used. The greatest disadvantage is that since the feed has been partially refrigerated and since the hydrogenation requires elevated temperatures, the over-all refrigeration load is increased. If addition of steam is required to control selectivity or polymer laydown on the catalyst, the gas must be redried.

Removal of the acetylene from the feed to the second ethylene fractionator has the same advantages and disadvantages as described for the feed to the first fractionator. Removal of acetylene at either of these points has the advantage over the removal of the acetylene from the product ethylene in that any polymers or tars, ethane or unreacted hydrogen from the hydrogenation step will be removed in the next step of purification. There are no known commercial installations where the acetylene is being hydrogenated at either of these points in the purification system.

Removal of acetylene from the high purity ethylene product has the advantage that the smallest quantity of gas is treated, thereby requiring the smallest equipment and the smallest quantity of catalyst. The refrigeration load is not increased; however, the hydrogen added for hydrogenation must have a high degree of purity or contamination of the ethylene will result, and a further step of purification may be required. It has the further advantage of having control over the quantity of hydrogen added, resulting in a relatively high degree of selectivity. The quantity of hydrogen required, of course, varies with the quantity of acetylene in the ethylene, which often depends on the source of the ethylene and the purification scheme used. If the ethylene results from the thermal cracking of hydrocarbons, the acetylene in the product ethylene may be ½-2%; if it comes from refinery off-gas, it may be less than 1%. Generally 2 to 3 moles of hydrogen/mole of acetylene hydrogenated are required to reduce the acetylene to a few parts per million. The quantity of pure hydrogen required in even small ethylene plants may make use of cylinder hydrogen uneconomical and require special production facilities for hydrogen.

As a result of the hydrogenation of relatively large quantities of acetylene, the purity of the ethylene may be reduced and the polymers formed may have an undesirable effect on the catalyst used in the production of the polyethylene as well as its quality. Generally, rare metal catalysts are used for hydrogenation of the acetylene at this point. Although there are known commercial installations where trace quantities of acetylene are hydrogenated at this point in the purification system, to our knowledge, there are none where appreciable quantities are hydrogenated.

Commercial applications

The hydrogenation of acetylene in ethylene streams has been conducted commercially over fixed bed catalysts. In some cases the catalyst has been in tubular reactors but in most instances the catalyst is contained in a relatively large bed with no provision for heat removal during the hydrogenation reaction. The reactors vary in size and shape, the design usually being dictated by economics. Catalyst bed depths are usually limited to about 10 ft. and the flow of process material is down through the bed. Special attention is paid to the design of the gas distributor to avoid disarrangement of the top of the catalyst bed which would result in attrition. Where periodic regeneration of the catalyst is required, multiple reactors, operating in parallel, are usually provided so as to reduce the quantity of catalyst to a minimum. Regeneration is usually accomplished by flowing steam, superheated to about 700°F., through the catalyst bed in a direction opposite that when on stream until no polymers are visible in the steam from the reactor. The addition of a small quantity of air, 3-5%, is often used to remove the components from the catalyst that are not volatized with steam.

Composition of the streams from which ethylene is recovered varies widely depending on the source. Table 1 shows the approximate composition of the unpurified gas streams as related to their sources. Various combinations of these streams are also often treated.

The quantity of such components as acetylene and butadiene present in the gas stream varies with the feedstock being cracked and the cracking conditions. Although it is

continued on next page

Acetylene removal

continued

always desirable to remove the acetylene as completely as possible with a minimum loss of ethylene, it is sometimes desirable to recover the butadiene and it is, therefore, desirable to avoid hydrogenating these components.

Several catalysts have been used for hydrogenating acetylene in ethylene streams. Although many catalysts have been described in the literature, only a few have been known to have been used successfully in commercial operations. In England, molybdenum sulfide on activated alumina was used as a catalyst to hydrogenate acetylene in coke-oven gas in the presence of sulfur compounds *(2)*. In Germany, during World War II, ethylene was produced by hydrogenating acetylene to ethylene over a palladium on silica gel catalyst *(3)*. It has also been reported that a nickel-chrome catalyst was used in Germany for the selective hydrogenation of acetylene to ethylene *(4, 5)*. In the U. S., to our knowledge, three general types of catalysts have been used for the selective hydrogenation of acetylenes in the presence of excess quantities of hydrogen, that is, in the gas stream before fractionation and concentration of the ethylene. One of these is a cobalt-molybdate-type catalyst *(6)*, which has been used most widely, the second is a nickel base catalyst *(7)*, reportedly used by the DuPont company, the third which is rapidly replacing the cobalt-molybdate catalysts is a nickel-cobalt-chromium catalyst *(8)*. All these catalysts are quite selective. For the hydrogenation of acetylene in the concentrated ethylene where the selectivity is controlled by the quantity of hydrogen added, palladium catalysts with various modifiers have been used *(9, 10)*. To our knowledge, their commercial use has been limited to the removal of relatively small quantities —a few hundred parts per million— of acetylene from the ethylene. No one has reported the use of these catalysts for the removal of acetylene from ethylene when it is present in appreciable quantities. Since the rare metal catalysts show no selective action, they have not been used for the removal of acetylene from gas streams containing a large excess of hydrogen.

The several factors that affect the activity and selectivity of the catalysts used for hydrogenating acetylene in the unpurified streams are (1) hydrogen partial pressure, (2) ethylene partial pressure, (3) partial pressure of C_4 and heavier hydrocarbons, (4) sulfur content of the gas stream, and (5) contact time. In general, the apparent activity of the catalyst is increased with an increase in hydrogen partial pressure and contact time and is decreased with an increase in the partial pressure of C_4 and heavier hydrocarbons and the sulfur content of the gas stream. The selectivity is increased as the partial pressure of hydrogen and ethylene is decreased, as the contact time is decreased and as the sulfur content is increased. Although the performance of the various catalysts now being used commercially is affected by the above factors, the quantitative effect is different with each.

Fleming *et al. (11)* have pointed out the possibility of a "run-away" reaction in which the ethylene is hydrogenated to ethane, resulting in a rapid increase in temperature. In actual commercial practice, there has been no difficulty in avoiding "run-away" reactions. In the few instances where hydrogenation of the ethylene occurred, the rate of temperature increase was such that it was easily controlled by stopping the flow of gas to the reactor. The only instances where there has been any tendency toward a "run-away" reaction has been while placing a new charge of catalyst on stream. After it has once been on stream there has been no tendency toward a "run-away."

The hydrogenation of acetylene and its derivatives in unpurified streams is reported to be commercially practiced over a special nickel catalyst *(7)*. This catalyst is reported to promote the selective hydrogenation of acetylene at pressures greater than 50 lb./sq. in. gauge and in the temperature range of 125-350°C. and in the presence of sulfur. The acetylene is reduced to less than 100 p.p.m. with less than 3% of the ethylene hydrogenated. Small quantities of steam may be added to improve the selectivity. Regeneration with steam is required every one to two months. After several regenerations, the catalyst may require resulfiding. There is no published information available giving a more exact effect of the above variables on the performance of this catalyst.

One of the more frequently used catalysts is a cobalt-molybdate-type catalyst *(6)*. With this type catalyst, the hydrogenation is usually conducted at a point in the system following the removal of the aromatic distillate but prior to drying the gas stream. It may precede or follow the carbon dioxide removal step, depending on the quantity and variability of hydrogen sulfide in the stream. This type catalyst is sensitive to changes in the variables previously described so that the exact catalyst used must be designed, taking in consideration the process conditions, the composition of the gas, the partial pressures and especially the sulfur content. Pressure variations of 10-15% may be compensated for by lowering or raising the operating temperature. At low concentrations of sulfur of a few parts per million, the effect on the activity of variations of two- to fourfold may be compensated for by varying the temperature 50-100°F. Higher variations and higher concentrations of sulfur require a catalyst of a different activity.

Commercial units are now operating where the feedstocks are any of those listed in Table 1 and at pressures of 75 to over 225 lb./sq. in. gauge. The hydrogenation is generally conducted at temperatures of 350-600°F. and space velocities of 500-1000 based on the standard volumes of gas contacting the catalyst per hour per volume of catalyst. Steam, 5-10%, is added to the process

Table 1. Composition of Streams as Related to Their Source

	Mole percent			
Component	Cracked ethane	Cracked propane	Cracked heavy hydrocarbons	Refinery gas
Methane	34	35	23	25 -40
Ethane	2	3	1	15 -25
Ethylene	33	36	24	5 -15
Propane	0.1	0.5	0.2	2 -10
Propylene	1	11	5	2 -10
Butenes	0.3	0.5	0.2	0.1 - 2
Butadiene	0.3	0.8	1	—
C_5 and higher	1	2	3	0.1 - 2
Acetylene	0.4	0.8	2	.01- 0.1
Hydrogen	27	11	19	10 -20
Carbon monoxide	1	1	12	0.1 - 1
Carbon dioxide	0.2	0.2	0.5	0.1 - 1
Sulfur	Trace	Trace	Varies	Varies
Nitrogen	—	—	12	1 - 5

gas to improve selectivity and retard the formation and deposition of polymers on the catalyst. During a cycle, which may be from two to four weeks, the inlet temperature is gradually increased by about 100-150°F. to compensate for the loss in activity of the catalyst resulting from deposition of polymers. At the end of the cycle the catalyst is regenerated with steam, or steam and air, reduced at 750-850° F. with hydrogen, cooled to operating temperature and placed on stream. The regeneration and reduction procedure generally requires 24-72 hr.

In general, the cobalt-molybdate catalysts are quite selective. The acetylene, including its derivatives, may be reduced from 1-2% to less than 10-20 p.p.m. with about 1-3% of the ethylene hydrogenated. Essentially none of the propylene or butene are hydrogenated and approximately 50% of the butadiene is hydrogenated.

The life of these catalysts has been one to two years. Although they generally show little loss in activity, spalling has been experienced which has determined their life. The catalyst cost has been 0.03-0.05¢/lb. of ethylene produced.

The function of the cobalt-molybdate-type catalysts in the removal of acetylene is to hydrogenate a portion of the acetylene to ethylene and ethane and to polymerize a portion; however, there is always a net loss of 1-3% of the ethylene. The temperature rise across a reactor indicates that as much as 50-75% of the acetylene and ethylene may be polymerized. Part of the polymers remain on the catalyst and are periodically removed by regeneration; part are carried along with the gas stream as vapors and are condensed in the coolers following the acetylene reactor.

Within the last year, a complex nickel-cobalt-chromium catalyst on a rugged support *(8)* has found extensive application for the hydrogenation of acetylene in the unpurified gas stream. This catalyst may be used at pressures over about 50 lb./sq. in. gauge. Although addition of steam to the process gas improves the activity of this catalyst, it may be used without adding steam at a somewhat lower temperature. The optimum operating temperature varies with the composition of the gas, the pressure, and the impurities present in the gas stream; however, the inlet temperature is generally in the range of 250-400°F. At space velocities of 1000-3000 the acetylene can be reduced from 1-2% to less than 10 p.p.m. with an over-all loss in ethylene of less than 1%. Essentially no propylene or butene is hydrogenated or polymerized. The quantity of butadiene hydrogenated depends on the degree to which the acetylene is removed. With essentially complete removal of acetylene, less than 5 p.p.m., most of the butadiene is hydrogenated to butene. If the hydrogenation is conducted at conditions of space velocity and temperature so that 100 p.p.m. or more acetylene remains unhydrogenated, only 0-5% of the butadiene is hydrogenated. Therefore, if it is desired to remove most of the butadiene to minimize fouling of the coolers following the acetylene reactor, operating conditions may be selected accordingly. However, if it is desirable to recover the butadiene, the acetylene reactor is then operated at conditions where 100 p.p.m. or more of the acetylene remains in the process stream to be removed from the product ethylene over a palladium catalyst. The frequency with which the nickel-cobalt-chromium catalyst requires regeneration depends on the composition of the process gas and the severity of the operating conditions; however, it is generally no more frequent than every three months and may be as long as six months. Regeneration is accomplished by steaming the catalyst at about 700-800°F. for 10-24 hr., followed by reduction with hydrogen at 700-800°F. for 6-12 hr. There is no information available on the life of this catalyst but due to its failure to show attrition, it has been estimated to be two to three years. The catalyst costs are estimated to be about 50% of those for the cobalt-molybdate catalysts.

The nickel-cobalt-chromium catalyst differs in several respects from the cobalt-molybdate catalysts. The effect on the selectivity of wide variations in gas composition, hydrogen and ethylene partial pressures, and contact time may be compensated for with relatively small variations in temperature. The sulfur content of the gas may vary from a few parts per million to 25-50 grains/100 std. cu. ft. and the effect on the activity compensated for by an increase in inlet temperature of the process gas of 10-100° F. The temperature rise between the inlet and outlet of the reactor is two to four times that with a cobalt-molybdate catalyst. This, along with the formation of appreciably fewer polymers, has been taken as an indication that the nickel-cobalt-chromium catalyst is predominantly a hydrogenation catalyst with a minimum of polymerization taking place over the catalyst.

Palladium and promoted palladium catalysts *(9, 10)* have been used commercially to hydrogenate relatively small quantities of acetylene in the product ethylene. Use of these catalysts offers the advantage of smaller reactors and requires smaller quantities of catalyst. However, the unit cost of the catalyst may be two to three times that of the previously described catalysts. Their use permits the recovery of butadiene without loss from hydrogenation. The operating pressure is usually that at which the ethylene is available and the operating temperature is generally 150-250°F. Space velocities of 1000-3000 are used. No steam is added and the ethylene remains dry. Hydrogen, 2-3 moles/mole of acetylene, is required to obtain relatively complete removal of the acetylene to less than 10 p.p.m. These catalysts have found their greatest application in reducing the acetylene content of ethylene from 20-100 p.p.m. to fewer than 10 p.p.m. To our knowledge, there is no commercial operation wherein relatively large quantities of acetylene are hydrogenated.

Use of these catalysts becomes unattractive when the quantity of relatively pure hydrogen necessary for hydrogenation requires the installation of special facilities for its production. The quantity of ethane and polymers formed depends on the quantity of acetylene present in the ethylene. Since, in many of the processes for the production of polyethylene, the presence of polymers is injurious to the catalyst performance and the quality of the product, an additional step of purification may be required. Likewise, residual hydrogen remaining from the hydrogenation step sometimes interferes in the polymerization process and its removal is necessary. More or less complete removal of sulfur from the ethylene must be attained or the life of the rare metal catalysts may be affected.

No information is available on catalyst cost or catalyst life.

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ethylene purification

Process design of Ethylene-ethane fractionator

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One of the most important industrial distillation separations is that between ethylene and ethane for the production of high-purity ethylene. Usually this separation follows (1) a demethanizing operation which removes essentially all components lighter than ethylene, and (2) a deethanizing operation which removes essentially all components heavier than ethane. Therefore, a true binary system usually exists. The purpose of this article is to show how the available data have been correlated by a new method into a useful relative volatility plot, how the plot is applied practically, and to report on some of the conclusions.

Data correlation

A. Data Sources. A limited amount of vapor-liquid equilibrium data (*4, 5, 7, 8*) is available for the ethylene-ethane system. Of these, only the data of Hanson *et al.* (*4*) and Hogan *et al.* (*5*) cover the temperature range commercially used for ethylene fractionation and appear to have enough precision to be used for an ethylene fractionation study. Upon thermodynamic analysis the Hanson *et al.* data show an inconsistency which suggests that the ethylene enrichment in the vapor was lower than the true equilibrium value (that is, the tray efficiency of the equilibrium cell was less than 100%). Alternatively owing to the recirculation of condensed vapors, it might be hypothesized that a liquid concentration gradient in the cell resulted in a nonrepresentative liquid sample. It is conjectured that this alternate hypothesis is the less likely.

B. Previous Correlation. Hanson *et al.* correlated their data isothermally considering each temperature level independently. Fifth-order equations with four constants were used. Their constants were evaluated to fit the Gibbs-Duhem relation and the Scatchard excess-free-energy relation exactly and then to give the best least-squares fit to the experimental data. If there is experimental error which is consistent, rather than random, throughout the data or if the precision of the data is low, this correlating technique mathematically forces poor agreement between correlation and data. Their poor agreement becomes evident when the effect of temperature on the activity coefficients is calculated from the Hanson *et al.* equations. Such an unusual temperature effect suggested a recorrelation giving primary emphasis to the experimental data points with a good interrelationship between the three temperature levels.

C. New Correlation. A technique based on relative volatility was used to recorrelate the vapor-liquid data. The volatility of ethylene relative to ethane was plotted vs. liquid composition using the experimental data points at each of the three temperature levels. This plot is shown in Figure 1. The smoothed relative volatilities were then cross-plotted at constant liquid composition against reciprocal temperature. This cross-plot is shown in Figure 2. With a little trial-and-error adjusting, it was possible to obtain straight lines. The lines as drawn in Figure 2 do not meet at a focal point, although had they been so drawn the fit to the data would have been about the same. To present the smoothed data in a more readily usable form, the relative volatility was plotted against temperature as shown in Figure 3. A Dühring plot (not shown) with ethane as the reference compound was used to obtain the constant pressure lines. Vapor pressures reported for ethane by Barkelew *et al.* (*1*) and for ethylene by York and White (*10*) were used for the Dühring plot.

D. Thermodynamic Test. Redlich and Kister (*9*) have pointed out and recommended as a test the following equation which is based on the Scatchard excess-free-energy equation:

$$\int_0^1 \log \frac{\gamma_i}{\gamma_j}\, dx_i = 0$$

where x = mole fraction in liquid phase
γ = activity coefficient for component in liquid phase
i and j refer to specific components.

When i is the more volatile component and the value of this integral is negative, this thermodynamic test suggests that equilibrium vapor phase compositions were approached, but not attained, that is, the tray efficiency was less than 100%. This thermodynamic test is shown in Figure 4 in which the Hanson *et al.* correlation and the present correlation are shown along with the experimental data points. This plot suggests that the tray efficiency of the equilibrium cell was slightly less than 100%, possibly 95% or more.

To explore the possibility that perhaps vapor-phase activity coefficients might be partly responsible for the negative values of the integral, the Benedict equation of state (*2*) was used to calculate ethylene and ethane vapor-phase activity coefficients for each experimental datum point. This equation predicted vapor-phase activity coefficients from 1.000 to 1.006 to ethylene and coefficients from 1.000 to 1.010 for ethane. These coefficients are too nearly ideal to explain the negative values of the integral. Also for mixtures this Benedict equation approach is empirical. Since no other means of evaluating vapor-phase activity coefficients for the ethylene-ethane system is currently available, further exploration of this possibility was abandoned.

Designing ethylene fractionator and auxiliaries

The relative volatility chart (Figure 3) can be used to produce a set of

curves which show minimum reflux, minimum trays, and theoretical trays as a function of reflux ratio for any combination of ethylene purity, recovery, feed composition and percentage vaporization, and operating pressure. Such calculations would result in numerous charts of only passing interest, therefore only three charts showing as many as possible of the above variables were prepared. Certain variables were fixed so as to approach commercial practice.

Minimum reflux ratios were first calculated, using the simple variation of the Gilliland method shown in Maxwell's Data Book on Hydrocarbons (*6*). This method requires an average α which is obtainable from Figure 3. Minimum reflux ratios were determined for three operating pressures, 36.6, 100, and 273 lb./sq. in. abs., and for fractionator feed compositions ranging from 30 to 80% ethylene, which cover the usual commercial operating range. Ethylene purity and recovery were each set at 98%. Current practice is to design for 98% and higher purity and high recovery. For the calculations liquid feed was assumed since usual practice is to liquefy the deethanizer overhead product prior to feeding it to the ethylene fractionator. Such liquefaction can be done at a higher refrigerant temperature level and is usually economic. Results are shown in Figure 5, which demonstrates principally that minimum reflux to feed ratio at a given pressure is nearly constant over a wide range of feed compositions for the ethylene-ethane system.

A more useful minimum reflux chart (Figure 6) was subsequently prepared showing minimum reflux to feed ratio as a function of column operating pressure for 95, 98 and 99 mol % ethylene product. Such a chart is useful for preliminary reflux estimates.

For illustration, several additional calculations were made. First, assuming all-liquid feed which was 50 mol % each ethylene and ethane, minimum trays at total reflux and theoretical trays at several operating reflux to overhead ratios were calculated. The Gilliland correlation of theoretical steps with reflux ratio (*3*) was used as a basic for calculation. Figure 7 shows a plot of results for 98 mol % ethylene product, based on 98% recovery. Additionally, theoretical tray requirements for 95, 98, and 99 mol % ethylene product purity using 1.25 times minimum reflux are plotted on Figure 7. This figure illustrates that 1.25 times minimum reflux is a good rule of thumb to use for ethylene fractionator design. Figure 7 may be cross-plotted to give a useful chart of theoretical trays vs. operating pressure for several ethylene purity parameters. The foregoing charts are necessarily rather specific, but show in general how the relative volatility chart which was prepared can be used to establish reflux and theoretical tray requirements for any ethylene fractionator. Had the Hanson et *al.* data not been recorrelated, the unusual temperature effect in their equations would not necessarily have led to the same conclusions.

As the final phase of the present study it was desired to determine the optimum pressure level for ethylene fractionation, based on energy require-

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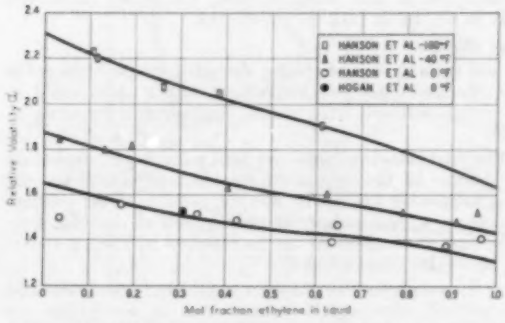

Figure 1. Volatility of ethylene relative to ethane at constant temperature

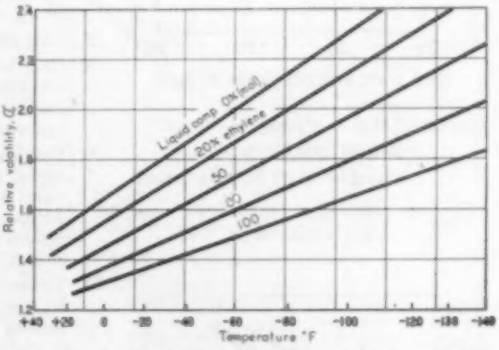

Figure 2. Ethylene-ethane system relative volatility vs. reciprocal temperature

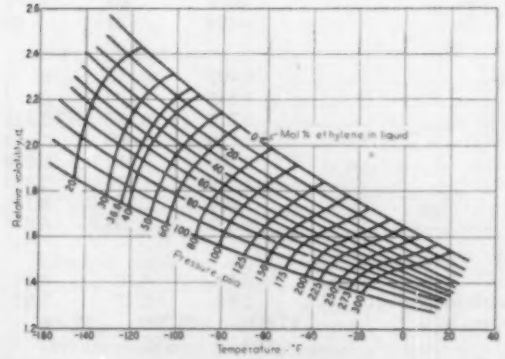

Figure 3. Volatility of ethylene relative to ethane in binary system

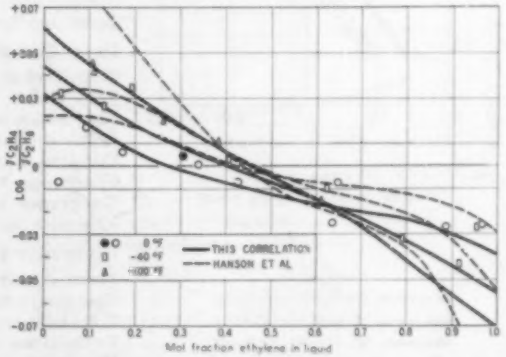

Figure 4. Thermodynamic test using Scatchard excess-free-energy relation

continued

ments (compressor horsepower). Premises established for the "optimum pressure" study are shown by Table 1.

Results of calculations are summarized by Table 2 for production of 120,000,000 lb./yr. ethylene. Figure 9 shows a plot of horsepower requirements vs. operating pressure. This figure shows that when ethylene is desired at high pressures, the tower should be operated at as high a pressure as is considered practical. The reason for this is that ethylene compression more than offsets the refrigeration compression savings at low pressures. If the feed is available only at low pressure, then feed pressure is the optimum tower pressure insofar as total horsepower is concerned. Tower diameter is essentially constant over the pressure range studied, illustrated by Figure 10. As a matter of information, total heat exchange area is also plotted as Figure 11. Total heat exchange surface appears to be minimum at pressures in the order of 100 to 200 lb./sq. in. abs. Referring to Table 2, it will be noted that maximum permissible heat leak to maintain a system heat balance is also shown. Maximum heat leak which can be tolerated without auxiliary refrigeration is 5 to 8% of the heat flow up the column. An ethylene fractionator is customarily insulated to give a much lower percentage heat leak.

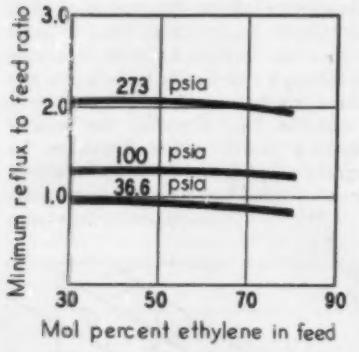

Figure 5. Minimum reflux vs. per cent ethylene in feed

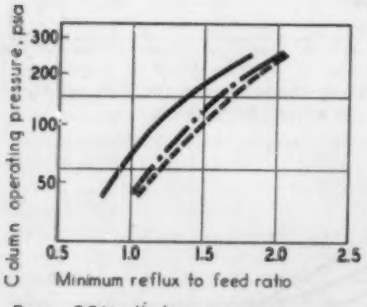

Figure 6. Minimum reflux for various column pressures

Conclusions

When correlating phase-equilibrium data it is necessary to consider the entire data network, rather than to consider each temperature level independently. A correlating technique plotting relative volatility against reciprocal temperature is a convenient and reliable method for smoothing phase-equilibrium data into a usable form for process design. The constant composition lines are straight. For the ethylene-ethane system this technique

Table 1. Premises for Optimum Pressure Study

1. Pressure: Tower top pressures studied are 36.6, 100, and 273 lb./sq. in. abs.
2. Reflux ratio: The reflux ratio is 1.25 times the minimum calculated at the feed composition.
3. Feed and products purity: Feed is a saturated vapor at −18°F., 280 lb./sq. in. abs. pressure containing 81.5 mol % ethylene and 18.5 mol % ethane. This is a practical composition in that it can be produced by tube cracking of liquefied petroleum gas (LPG). The overhead product is 99.5 mol % ethylene delivered as a vapor. Design ethylene recovery is 99.5%, which yields 97.8 mol % ethane as kettle product.
4. Work of compression: Compressor efficiency is taken as 70%, based on the isentropic work of compression.
5. Temperature approach in heat exchange: The temperature difference at the closer end of the exchanger is 0.0232 times the lower absolute temperature. This is an approach of 9 to 10°F.
6. Pressure drop: Tower pressure drop is 0.05 lb./sq. in. actual tray. Line drops will be assumed equal to the loss in one exchanger. Exchanger pressure drops for each side are 3.0 lb./sq. in. at 273 lb./sq. in. abs., 1.4 lb./sq. in. at 100 lb. sq. in. abs., and 0.75 lb./sq. in. at 36.6 lb./sq. in. abs.
7. Tray efficiency: The tray efficiency is 70%.
8. Heat leaks: Heat leaks are ignored in determining the refrigeration horsepower requirement. However, the maximum permissible heat leak is determined as the heat leak beyond which auxiliary refrigeration equipment is required to maintain a heat balance.
9. Refrigeration scheme: The refrigeration scheme is a heat pump cycle, expanding liquid ethane from the bottom of the column to provide refrigeration for the reflux condenser, and recompressing the ethane into the reboiler of the column. Before compression the ethane is heat-exchanged against itself to raise the temperature level so that the heat of compression can be removed by cooling water. Figure 8 illustrates the above-described scheme.
10. Tower sizing: The tower diameters for the pressures considered are determined by the Brown-Souders method, allowing downcomer area at one gallon per minute of liquid per square inch of downcomer.

Table 2. Summary of Results for 120,000,000 lb./yr. Ethylene

Column pressure, lb./sq. in. abs.	36.6	100	273
Tower top temperature, °F.	−124	−81	−23
HEAT EXCHANGER DUTIES	MILLION B.T.U./HR.		
Feed-ethylene exchanger	0.427	0.278	0
Feed chiller	2.545	2.530	0
Feed-ethane exchanger	0.715	0.438	2.540
Reflux condenser	4.710	5.860	7.250
Compressor exchanger	2.250	2.555	2.276
Compressor aftercooler	1.570	1.975	2.325
Compressor work	1.665	2.080	2.145
Maximum heat leak	0.392	0.348	0.348
EQUIPMENT SIZES			
Tower diameter, ft.	5.14	4.76	4.89
Operating reflux ratio on overhead product	1.64	2.27	3.52
Total heat exchange surface, sq. ft.	27,600	21,700	25,000
Refrigeration hp.	652	792	841
Horsepower to compress ethylene to 273 lb./sq. in. abs.	629	256	0
Total hp. required	1,281	1,048	841

gives results reasonably consistent with thermodynamic relationships.

ACKNOWLEDGMENT

The authors wish to acknowledge their indebtedness to Phillips Petroleum Company for permission to publish this paper and to K. H. Hachmuth, who suggested the recorrelating technique, for his guidance.

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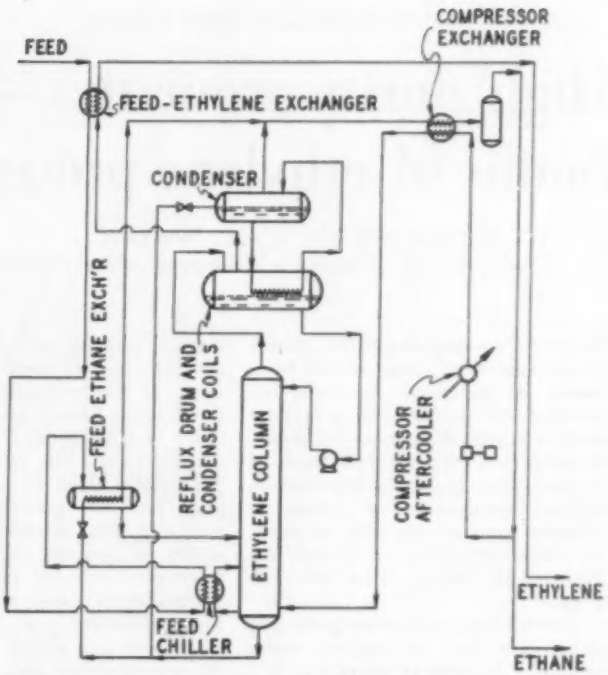

Figure 8. Ethylene-ethane fractionation scheme

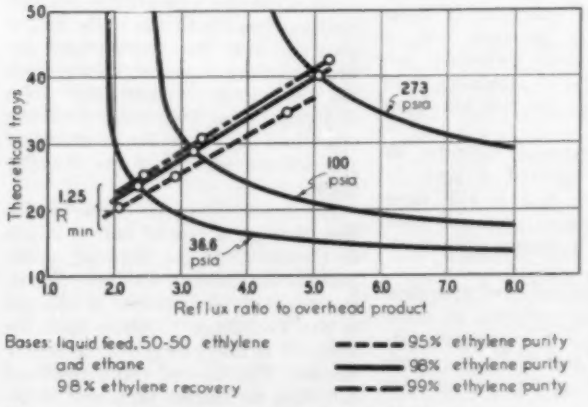

Figure 7. Reflux ratio vs. theoretical trays

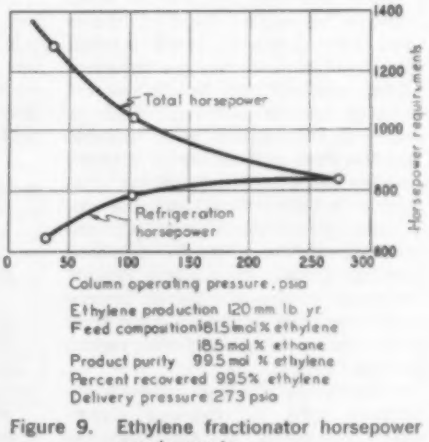
Total horsepower
Refrigeration horsepower
Horsepower requirements
Column operating pressure, psia
Ethylene production 120 mm lb yr
Feed composition 81.5 mol % ethylene
18.5 mol % ethane
Product purity 99.5 mol % ethylene
Percent recovered 99.5% ethylene
Delivery pressure 273 psia

Figure 9. Ethylene fractionator horsepower requirements

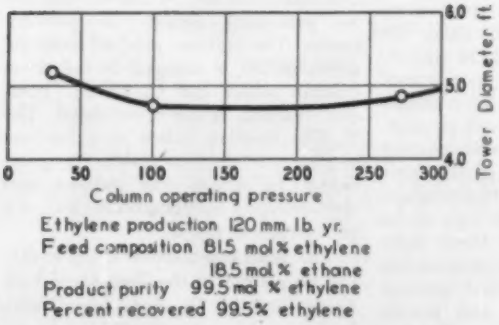
Tower Diameter ft
Column operating pressure
Ethylene production 120 mm lb yr
Feed composition 81.5 mol % ethylene
18.5 mol % ethane
Product purity 99.5 mol % ethylene
Percent recovered 99.5% ethylene

Figure 10. Ethylene fractionator diameter requirements

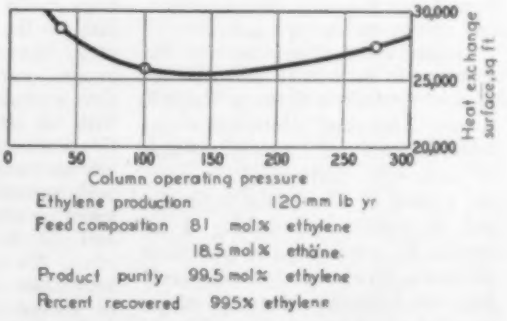
Heat exchange surface, sq ft
Column operating pressure
Ethylene production 120 mm lb yr
Feed composition 81 mol % ethylene
18.5 mol % ethane
Product purity 99.5 mol % ethylene
Percent recovered 99.5% ethylene

Figure 11. Ethylene fractionator heat exchange area requirements

ethylene manufacture byproducts

High purity aromatics—bonus of ethylene process

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Universal Oil Products Company, Des Plaines, Illinois

In 1957 more than two billion pounds of ethylene were manufactured by a variety of techniques involving the pyrolysis, or cracking, of a heavier hydrocarbon in the presence of steam. In addition to ethylene, a multitude of hydrocarbons appear in the reaction product—the gamut from methane to a heavy aromatic tar plus hydrogen and coke—regardless of whether the feed is pure ethane or as heavy as a gas oil.

The C_5-plus and heavier portion of these pyrolysis by-products were originally considered worthless as a source of petrochemicals and useful only as a blending stock in motor gasoline. The analysis shown in Table 1 of a typical depentenized and rerun pyrolysis by-product "light oil" shows some of the properties. It will be noted that the high gums, the low induction period, and the high diolefin content indicate that even though high in octane this material is quite unstable and therefore undesirable as a motor gasoline blending stock. Even after caustic washing and suitable inhibiting, this material may not constitute more than about 5% of a total gasoline blend. As gasoline quality requirements are tending to become more and more stringent, most light oil producers are seeking other outlets for this material.

Actually the C_5-plus pyrolysis by-product light oil contains significant proportions of such valuable petrochemicals as butadiene, cyclopentadiene, isoprene, benzene, toluene, xylene, styrene, and indene.

A more detailed breakdown of the components in various ethylene by-product light oils is shown in Table 2. Several interesting observations can be made from this. Large proportions of aromatics, particularly benzene, are present in all of these light oils, and as severity of cracking is increased the paraffin and olefin content decreases. This is seen to be especially true with light oil produced by oil gas cracking (a very severe form of cracking); here the C_5-plus by-product fraction contains over 80% aromatics and there are no paraffins present.

In the steam-cracking of naphthas the benzene formed can amount to as much as 25% by weight of the ethylene produced. The pyrolysis of propane yields about 15 pounds of benzene per 100 pounds of ethylene produced. It is estimated that the availability of benzene alone from the by-product light oils produced in the United States is approximately 55 million gallons per year. The quantities of toluene and xylene produced, although somewhat less, still represent a considerable quantity and are estimated at 22 and 10 million gallons per year respectively.

Although these light oils contain such considerable quantities of these valuable products, presently only a few of the ethylene producers are recovering high purity chemicals from them. The reason for this has been twofold:

(1) The extreme difficulty in processing a material of such diolefinic nature that it will form large quantities of gum and coke upon heating in process equipment, and

(2) The difficulties of separation caused by the presence of many hydrocarbons and azeotropic mixtures having essentially the same boiling point as the product desired.

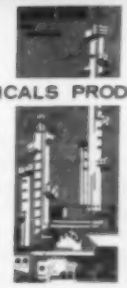
In order to recover high purity aromatics from those light oils, it has been found necessary to remove or saturate the olefins and diolefins, remove contaminants such as sulfur, oxygen, and nitrogen compounds, and then separate the individual aromatics from the other hydrocarbons present. Conventional methods of acid treating are uneconomic because of the high acid consumption and hydrocarbon losses associated with the high olefin and diolefin content of these light oils. Normal hydrodesulfurization techniques cannot be applied because of excessive exchanger and heater fouling caused by the diolefins present.

Universal Oil Products Company has developed the Two-Stage Unifining Process as a solution to these problems, whereby hydrocarbon feeds containing diolefins can be processed so as to yield a completely hydrogenated, sulfur-free product without the gum and coke formation normally associated with these stocks. The process essentially consists of selective hydrogenation of the light oils carried out in a manner which insures economic, long on-stream periods of operation.

Olefins and diolefins are selectively hydrogenated to their respective paraffinic or naphthenic structures in such a manner that polymerization reactions are minimized. Contaminants such as sulfur-, nitrogen- and oxygen-containing hydrocarbons are eliminated by the controlled breaking of the molecular chain or ring at the point, or points, where the sulfur, nitrogen and/or oxygen atoms are attached. This is accompanied by the simultaneous introduction of hydrogen and the evolution of hydrogen sulfide, ammonia and/or water. In this manner such compounds as thiophenes, mercaptans, pyrroles, pyridines, and various phenols are reduced to negligible quantities in the final aromatic product. As the hydrocarbon reaction products from both the olefin hydrogenation and the contaminant destruction have a greater volume than did the parent reactants, the yields of liquids from Two-Stage Unifining operations are normally in excess of 100 volume percent of the charging stock.

A schematic diagram of the process flow through a typical unit is shown in Figure 1. As the isoprene, cyclopentadiene, indenes, and any coumarones would be destroyed if charged to the Two-Stage Unifining unit, the light oil is first charged to a depentanizer. The C_5 cut taken overhead can then be further processed to recover isoprene and cyclopentadiene, used for synthetic rubber and insecticide manufacture, or the C_5 cut can be processed directly to produce resins. The bottoms product from the depentanizer is charged to the rerun column where the C_6 to C_9 "heart cut" fraction is taken overhead. The C_9-plus fraction, taken as a bottoms product, is then available for processing to utilize the indenes and styrene-type hydrocarbons for the production of resins.

The heart cut fraction is the hydrocarbon charge to the Two-Stage Unifining unit. It is first mixed with hydrogen, heated and charged to the reactor section where it is hydrodesul-



furized over a specially prepared cobalt-molybdenum catalyst in such a manner as to eliminate heat exchanger and heater fouling.

The reactor effluent is cooled and charged to the product separator. Most of the hydrogen-rich separator gas is recycled back to the reaction section, and supplemented with make-up hydrogen. The remainder, only a small stream, is vented from the system as a purge to remove contaminants. The separator liquid is charged to the stripper where the small amount of C_5 and lighter hydrocarbons present are fractionated from the hydrogenated product together with H_2S, H_2O, and NH_3.

The make-up hydrogen required can be obtained from a variety of sources, provided that the supply contains at least 50% hydrogen. The high pressure off-gas from a Platforming® unit is particularly useful for this purpose. Vent gas from the demethanizer of the ethylene recovery system was used successfully in one design. The amount of hydrogen required will vary with the sulfur and olefin contents of the light oils. For stocks that we have tested the hydrogen requirement has varied between 100-340 std. cu. ft./bbl. of charge.

This flow scheme is quite flexible in respect to the composition of the hydrocarbon being charged. Light oils containing wide variations in diolefin, olefin, sulfur, nitrogen, and other contaminants can be processed without difficulty. It is also very interesting to note that this scheme can be used to process coke oven light oils as well as ethylene and oil-gas by-product light oils. However, conventional acid treating and distillation techniques can not economically be applied to ethylene by-product light oils. This is because the high diolefin and olefin content of the light oil make acid consumption prohibitive and the presence of relatively large quantities of paraffins precludes the use of distillation to produce high purity aromatics because of azeotroping.

Results obtained from a commercial Two-Stage Unifining unit when processing an ethylene co-product light oil are shown in Table 3.

Note that the diolefins and olefins have been essentially completely saturated. Polymerization reactions have been substantially eliminated as is evidenced by comparing the distillation data for the feed with that for the product. The amount of aromatics saturated is so small that this can actually be referred to as negligible, since the inherent inaccuracies of analytical techniques could account for the 0.6 percent of aromatic saturation indicated. The hydrogen consumption of 310 std. cu. ft./bbl. is quite close to the theoretical amount needed for saturations of the olefin and diolefins.

This plant has been in continual commercial operation for approximately seven months without any indication of heat exchanger or heater fouling or of loss of catalyst activity.

In the past, the purification of aromatic-containing streams has been accomplished by batch distillation or extractive distillation. Batch distillation requires the discarding of intermediate fractions on either side of the desired aromatic thereby giving low yields and providing no escape from azeotroping paraffins or naphthenes. Extractive distillation requires prefractionation of the aromatic mixture into narrow boiling range concentrates including the boiling point of the desired aromatic, each of which would then be processed separately. These techniques have only been able to produce benzene having about 4.5 to 5.0°C. solidifying point at recoveries of less than 90%. The high operating cost and low product purities obtained in these processes are such as to make the products so made prohibitively expensive in present day chemical markets.

However, we have witnessed the development and economical application over the past six years of a new separation technique, the Udex® Process, discovered by Dow Chemical Company and developed, licensed, and engineered by Universal Oil Products Company. Benzene has been produced at one commercial Udex plant in yields consistently exceeding 99.9%, the product having a 5.50°C. freeze point—extremely close to the API value of 5.533°C. for the most highly purified research grade benzene.

The Udex liquid-liquid extraction method has been recently described in this journal by Grote *(1)*, together with data from commercial applications in the separation and purification of aromatics from various feedstocks. Therein it was shown that the aromatics produced not only meet established ASTM "Nitration Grade" specifications, but exceed them, as illustrated by Tables 4 and 5 for commercial Udex benzene and toluene.

The high quality of Udex products is based on the solubility and selectivity differences of the aqueous glycol solvents for various types of hydrocarbons. The exact composition of the solvent for a given application is tailored to permit the use of optimum operating conditions. The nature of the solvent and the process techniques used keep utility requirements very low.

It is somewhat difficult to generalize on the economics of a Two-Stage Unifining and Udex installation to recover high purity aromatics from ethylene manufacture, because of the wide variety of feed stock composition and an even wider practical range of capacities. However, in Tables 6, 7, and 8 are shown the results of a preliminary economic study on what we believe to be an "average" case. Therein we have assumed that two thousand barrels per stream day of a C_3-plus ethylene by-product light oil are available from which it is desired to produce the maximum yields of high purity benzene, toluene, and xylenes; plus a C_5 and a C_9 cut, each

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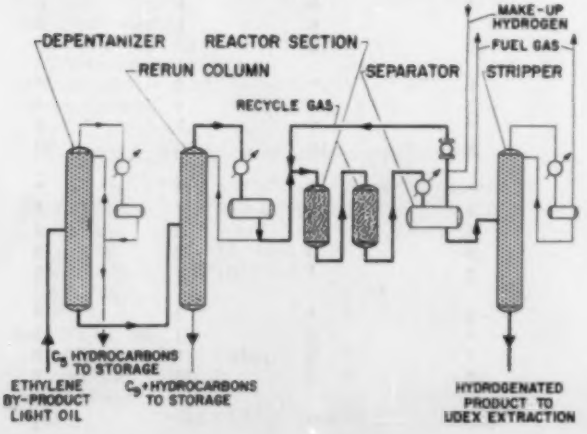

Figure 1. Two-stage Unifining

continued

of which could be further processed for the production of petroleum resins or insecticides. Based on commercial experience in plants processing by-product light oils, this study is considered to be conservative.

Table 6 shows the estimated yield structure for the Two-Stage Unifining and Udex treatment of the 2,000 barrels per stream day of by-product light oil. The process equipment would be as previously shown for the Two-Stage Unifining, and the Udex units (described by Grote), with the addition of a benzene column, a toluene column, and a xylenes column for the separation of the final high purity products from the Udex extract. It will be noted that the over-all recoveries of the different aromatics are quite high.

It is estimated that the total erected cost of the process equipment would be $2,270,000. This cost includes the feed depentanizer and rerun columns as well as the three postfractionation columns of the Udex unit. The inclusion or exclusion of different hydrocarbon fractions from the Two-Stage Unifining unit's feed would, of course, influence this value.

A breakdown of the operating costs involved is shown in Table 7. Labor costs are modest. Both units are instrumented for operation with a minimum of human attention. The utilities estimate is based on a Gulf Coast installation and assumes the use of steam for reboiling all of the fractionators and the Udex stripper. Fuel gas (fired reboilers) can be substituted for most of the steam consumption if desired. The catalysts and chemicals consumptions shown are conservative estimates based on commercial experience from many operating units.

Since neither the Unifining* nor the Udex process contains any corrosive catalysts or chemicals, and as the units are designed to obtain a high on-stream efficiency (350 stream days per year has been used for this study), the cost of maintenance and turnarounds is quite low. We have conservatively estimated the maintenance allowance at 3% of the erected cost.

Because aromatics are a high volume chemical, the sales expenses are not as high as required for many specialty products. However, they are somewhat more than required for the sale of gasoline or fuel oil. We have estimated the allowance for administrative and sales overhead at 5% of the sales value of the products. Depreciation has been taken over a ten-year period and the average interest rate used was 3%.

Based on these considerations, the total operating cost for recovering high purity aromatics from 2,000 barrels of ethylene light oil would be approximately $2,600.00 per calendar day or 4.7¢ per gallon of aromatics recovered.

Table 8 is a profitability calculation for this operation. Prices for benzene, toluene, and xylenes are those quoted in the September 1, 1958 issue of the *Oil, Paint & Drug Reporter*, f.o.b. plantsite. The value of the C_5 and C_9-plus fraction will vary depending on the amount of the desired compounds such as cyclopentadiene, isoprene, indenes, and coumarones that are present. The value for the raffinate is based upon its being blended into regular grade motor gasoline. It is felt that the prices used are conservative. The total revenue from such stocks would amount to more than 6.7 million dollars per year.

Although the ethylene by-product light oil is relatively high in octane, its high gum and diolefin content render it unsuited for use in *premium* gasoline even when inhibited. The price of 11¢ per gallon used for costing the light oil then must take into consideration the fact that it can only be used as a blending stock in *regular* grade gasoline. In actuality its value as an unprocessed raw material might even be somewhat less than this because of the

* Trademark.

Table 1. Ethylene By-Product Depentanized and Rerun Light Oil From Naphtha Pyrolysis

API Gravity	35.0		
Boiling Range		Gum (mg./100ml.)	
IBP	154°F	Copper Dish	718
10%	185°F	Existent	10.0
50%	282°F	Potential	3210
90%	349°F		
EP	381°F		
Induction Period	70 Minutes	*Diene Value*	10.6
Color,	Union 1½	*Octane* F-1 Clear	99
Bromine Number	55	*Total Sulfur*	0.1 wt. %

Table 3. Commercial Unifining of Light Oil From Ethylene Manufacture

	Feed	Product
API, °	34.8	37.3
IBP, %	154	154
10%	184	178
50%	214	210
90%	281	278
EP	332	350
Octane F—1 + 3 ml. TEL/gal.	103.9	105.1
BPSD	500	510
Bromine No.	43.2	0.5
Diene Value	9.5	0.1
Total Sulfur, Wt. %	0.038	<.005
Contained Aromatic	373 BPSD	370 BPSD
Aromatic Saturation	0.6%	
Hydrogen Consumed	310 SCF/Bbl.	

Table 2. Analysis of Typical Light Oils

Hydrocarbon Types	Vol. % from Propane Pyrolysis	Vol. % from Low Severity Naphtha Pyrolysis	Vol. % from High Severity Naphtha Pyrolysis	Vol. % from Oil Gas Pyrolysis
C_4 Diolefin	11	10	3	5
C_4 Olefin	6	13	1	•
C_4 P + N	4	9	1	0
C_5 Diolefin	2	3	2	2
C_5 Olefin	4	8	1	3
C_5 P + N	1	5	1	0
C_5 Benzene	37	19	27	63
C_7 Diolefin	1	•	2	•
C_7 Olefin	3	•	•	•
C_7 P + N	•	7	1	0
C_7 Toluene	8	10	23	20
C_8 Diolefin	•	•	•	•
C_8 Olefin	1	1	•	•
C_8 P + N	•	1	2	0
C_8 Aromatics	3	5	12	3
C_8 Styrene	2	•	7	1
C_{9+} Diolefin	2	•	1	•
C_{9+} Olefin	•	2	1	1
C_{9+} P + N	•	2	•	0
C_{9+} Aromatics	15	5	15	2
• *less than 1*	100	100	100	100

treating, inhibiting, and difficulty of handling that is necessary before it can be blended into regular grade gasoline. The operating costs used are those obtained from the previous table.

A gross profit of approximately $2.5 million is obtained by this calculation, which after allowing for income tax, yields an estimated net profit of approximately $1.2 million per year. On this basis the pay-out period, obtained by dividing required investment by the sum of the net profit plus depreciation allowance, is a very attractive 1.6 years.

All of these economic factors will vary, of course, depending on the quantity of light oil that is available and on the location of the plant. Commercial units have been designed in capacities ranging from 400 bbl./stream day to 3500 bbl./stream day of light oil feed. One manufacturer is planning to supplement his available ethylene by-product light oil feed stock with coke oven light oils.

In summary, present practices of blending these unstable ethylene by-product light oils into motor gasoline will not long continue to be permissible if the trend toward higher quality motor gasoline is maintained. A processing technique has been discussed which will permit ethylene and coke producers to process their light oils—no matter what their composition—to enable recovery of an exceptionally high yield of highest purity aromatics.

Presented at the New York Section, A.I.Ch.E., One-Day Meeting, October 1958.

Table 6. Aromatics Recovery From Ethylene By-Product Light Oil By Two-Stage Unifining and Udex

	Estimated Yields		
	Feed Stock BPSD	Products BPSD	Recoveries
Light Oil	2,000		
Hydrogen	(350 MSCF/D)		
C_5s		110	
C_{9+}		320	
Benzene		520	99.5%
Toluene		400	95 %
Xylenes		350	90 %
Raffinate		300	

Table 7. Aromatics Recovery From Ethylene By-Product Light Oil By Two-Stage Unifining and Udex

Operating Costs (350 SD/yr.)

		$/Calendar Day
Operating Labor		
One operator per shift @ $3.00/hr.	72	
Two helpers per shift @ $2.50/hr.	120	
Supervision, estimated	40	
		232
Laboratory		
One tester per day @ $2.50/hr.	20	
Supplies, estimated	10	
		30
Utilities		
Steam (150 psig) 37,000 #/hr. @ 30¢/M	255	
Fuel Gas 8 MM BTU/hr. @ 15¢/mm BTU	28	
Cooling Water (30°F. Rise) 3250 GPM @ 2¢/M Gal.	90	
Power, 240 KW @ 8¢/KWH	44	
		417
Catalyst and Chemicals		
Unifining Catalyst	45	
Glycol	65	
Misc. Chemicals	10	
		120
Maintenance Allowance		187
Allowance for Administration and Sales Overhead		850
Depreciation		622
Interest on Investment		187
		$2,645/CD or 4.67¢/gal. of aromatic produced

Table 4. Properties of Commercial Benzenes

	ASTM Spec.	Plant "A"	Plant "B"
Specific Gravity	0.8820-0.8860	0.8833	0.8849
Distillation Range			
I.B.P.-E.P., °C.	1.0 Max.	0.7	0.9
Included Temp., °C.	80.1	OK	OK
Solidifying Point, °C.	4.85 Min.	5.29	5.51
Acid Wash Color			
Acid Layer	2 Max.	1+	0
Hydrocarbon Layer	0	0	0
Bromine Index	No Spec.	1.0	<1
Toluene Content	No Spec.	<0.1	—

Table 5. Properties of Commercial Toluenes

	ASTM Spec.	Plant "A"	Plant "C"
Specific Gravity	0.8690-0.8730	0.870	0.872
Distillation			
Range, °C.	1.0 Max.	0.4	1.0
Included Temp., °C.	110.6 ± 0.1	—	—
I.B.P., °C.	—	110.7	110.2
E.P., °C.	—	111.1	111.2
Acid Wash Color			
Acid Layer	2 Max.	0+	0
Hydrocarbon Layer	0	0	0
Paraffin Content, Vol. %	1.5 Max.	Nil	Nil

Table 8. Aromatics Recovery From Ethylene By-Product Light Oils By Two-Stage Unifining and Udex

Profitability

Revenues			$/Year
Benzene	520 BPSD @ 31¢/gal.		2,370,000
Toluene	400 BPSD @ 25¢/gal.		1,470,000
Xylenes	350 BPSD @ 28¢/gal.		1,440,000
C_{5-} Fraction	110 BPSD @ 15¢/gal.		242,000
C_{9+} Fraction	320 BPSD @ 15¢/gal.		705,000
Raffinate	300 BPSD @ 11¢/gal.		485,000
		Total	6,712,000
Cost of Manufacturing			
Feed Stocks			
Light Oil	2,000 BPSD @ 11¢/gal.		3,240,000
Hydrogen	350 MSCF/D @ 15¢/MM BTU		6,000
Operating Costs			966,000
		Total	4,212,000
Gross Profit			2,500,000
Allowance for Income Tax @ 52%			1,300,000
Net Profit			1,200,000

Payout Period $= \frac{\$2,270,000}{1,200,000 + 227,000} = 1.6$ years

SOLIDS PROCESSING

centrifugation

Miniature Hydrocyclones —

energy requirements and solid elimination efficiency

Part 1 - Energy requirements

D. E. Matschke[1] and D. A. Dahlstrom[2]

From experimental work reported in Part 1 on small glass hydrocyclones, the cyclone energy requirements at any particular capacity are given by a simple formula. Experimental results exhibited an average deviation of 4 to 5%. The equation is similar to that developed earlier for large diameter units with the exception of the proportionality constant. The somewhat higher value obtained in this study was felt to be due to the smaller included angle and the smoother glass surface.

THE LIQUID hydrocyclone has become widely accepted as a powerful classifying tool in the metallurgical, coal, chemical, and other processing industries. Reasons for this rapid acceptance are several:

1. Produces a sharp classification curve with efficiencies well above other classifiers.
2. Highest capacity per unit cross-sectional area of any classifier thereby minimizing floor-space requirements.
3. Contains no moving parts, is simple in construction, and minimizes capital investment.
4. Handles a wider range of feed solids concentration with lower resultant particle-size separations than gravitational classifiers.
5. Produces a thickened underflow containing the coarser fraction which is suitable for filtration and final dewatering or recirculation within the process as necessitated by flowsheet requirements.

Industrial liquid cyclones have been employed in sizes ranging from 3-in. to 3-ft. diam. or even larger, with flow rate capacities of about 10 gal./min. to several thousand gallons per minute. Classification range, depending on feed solids concentration, and solid and liquid specific gravity, has varied from approximately 20 μ to 20 mesh yielding a wide field of application.

However, many industrial problems require classifications well below 20 μ for maximum recovery or process reasons. Such separations necessitate either extremely high centrifugal forces or appreciable retention time at

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lower centrifugal forces. As retention time within the liquid cyclone is very small, higher centrifugal force fields represent the most logical way to further improve its separation power. Centrifugal force generated is not a major function of cyclone diameter. However, because of the required ratios that must be maintained between feed and overflow diameters and the cyclone diameter for maximum efficient transformation of feed pressure into rotational kinetic energy, smaller diameter cyclones will produce higher centrifugal forces. Accordingly, investigations have been made on cyclones as small as 4-mm. diam. (*11*). Results have indicated the possibility of separations down to the 1- to 10-μ region which can significantly increase the application of the liquid cyclone.

Typical uses or studies already made with 10- to 30-mm. diam. cyclones are the separation of starch from gluten, separation of corrosion particles from coolant streams in nuclear reactors, and removal of fine particles from green liquor in the recausticizing steps of sulfate kraft mills.

Development of equations to predict particle-size classification, flow capacity, and energy requirements are necessary in order to achieve maximum and optimum application. Several previous studies have furnished this information for the larger cyclones (*5, 6, 7, 8, 10, 15*). Extrapolation of these equations to the small diameter units is not necessarily warranted due to the much higher centrifugal forces, increased shear, and the small distance between the outer and inner vortex radii. Accordingly this study was initiated to investigate these important parameters. For simplicity this article will be divided into two sections: (1) Energy Requirements and Flow Capacity, and (2) Solid Elimination Efficiency.

Energy requirements and flow capacity

Theory. The most common form of the liquid cyclone consists of a cylindrical section at the base of which is an inverted conical section. The feed nozzle is attached tangentially to the cylindrical section and usually at an angle sufficient to give the feed a small downward component of velocity so that at the completion of one revolution, the fluid and solids do not interfere with the entering feed.

The fluid dynamics examination pursued by Driessen (*9*) and the experimental attack applied by Kelsall (*12*) substantiate that the main flow of a liquid cyclone is manifested in an outer free vortex established by the tangential entry. This flow network occupies all but a narrow, almost cylindrical, central tube of the cyclone volume. The central core consists of a forced vortex that, while it is fed from the free vortex and has the same rotational direction, has a net flow direction opposite that of the free vortex. The free vortex is the source of the underflow stream while the forced vortex contributes the overflow stream. As proved experimentally by Kelsall, critical separation occurs at the outer radius of the forced vortex which is the inner radius of the free vortex (*10*). This radius is approximately equal to the cyclone overflow radius.

At the top of the cylindrical section of the cyclone there exists some secondary flow patterns due to the presence of the cyclone top and outer wall of the vortex finder. This represents an area of inefficiency. In proper cyclone design, as shown by earlier work (*5, 6, 15*), such secondary flows should be minimized although it is impossible to remove them altogether. With proper design, this inefficiency can be lowered to a small value. Figure 1 illustrates the typical bulk flow pattern in the liquid cyclone.

Kelsall's experimental work on a 3-in. diam. cyclone with water slurries indicated the following relation for the tangential velocity distribution in the free vortex,

$$V_t = K'/r^a \qquad (1)$$

where a varied from 0.77 to 0.84 and was primarily a function of the kinematic viscosity of the fluid (*12*). For an ideal, inviscid fluid, the theoretical velocity distribution within a free vortex would yield the same equation with the exponent a equal to 1.0.

Banerji and Roy predict exponent a equal to 0.50 based upon the Navier-Stokes equation assuming viscous flow and after making certain simplifying assumptions about the free vortex boundary conditions (*1*).

The proposed tangential velocity equations within the free vortex all predict infinite velocity at the cyclone axis. This naturally does not occur but rather, the free vortex flow appears to go through a sharp transition to a forced vortex in the vicinity of the overflow or vortex-finder radius. With the forced vortex the tangential velocity obeys the following relation:

$$V_t = K''r \qquad (2)$$

It is evident then that the tangential velocity goes through a maximum in the vicinity of the vortex finder radius.

It is interesting to note the extremely high centrifugal force available at the critical separation point at the outer radius of the forced vortex. In Kelsall's work, maximum tangential velocities of over 40 ft./sec. were measured (*12*). If a 1-mm. radius vortex finder is employed and a tangential velocity of 40 ft./sec. assumed, centrifugal force would be 15,130 g.

It is evident that velocity components other than tangential, i.e., the vertical and the radial velocities, play important roles in the operation of the cyclone. The vertical velocity determines the volume split between the overflow and underflow while the radial velocity sets up the fluid current against which the solid particle must settle to effect separation.

In a previous article, empirical correlations were developed for the energy requirements and capacities of cyclones with diameters of 3 in., or greater, operating on water slurries as follows (*5*):

$$\frac{(\mathrm{GPM})'_f}{(\mathrm{F})^{0.50}} = K/of^{0.50} \qquad (3)$$

It should be emphasized that the $(\mathrm{GPM})'_f$ is the feed rate in gal./min. minus the volume rate of the solids present in the underflow whose particle size is greater than the top size found in the overflow. This latter volume rate is determined at the maximum slurry solids concentration which the cyclone could produce in the underflow for the particular solid specific gravity. Water was employed in developing Equation (3) and in this case the total feed rate was correlated. However, when slurries were tested, larger rates than predicted by the equation were experienced. It was reasoned that the coarse particles were instantaneously thrown to the cyclone wall and thus represented a negligible amount of energy loss. After the correction to the feed rate as stated above was made, agreement of energy requirements for slurries with the Equation (3) developed on water was proven.

The constant, K, was found to be a function primarily of cyclone included angle and distance between conical section and vortex finder. The K value ranged from 5.5 to 6.5 with units as indicated, and was found to increase with decreasing apex angle and increasing distance. It was found that capacity was independent of cyclone diameter but that it was necessary to

continued

Miniature hydrocyclones

continued

design with given optimum geometries to yield the sharpest classification at a minimum size for a given set of cyclone operating conditions (*5, 15*). This phase of cyclone design will be covered in the equipment discussion.

Haas, *et al.* in a recent examination of energy requirements in water slurries for cyclones of less than 3-in. diam. and more specifically cyclones of 0.16,-0.25,-0.40- and 0.50-in. diam., determined the following empirical equation (*11*).

$$F = \frac{K''' (\mathrm{GPM})_f^{2.27}}{D^{0.8} f^{1.3} o^{2.0}} \qquad (4)$$

When a set of optimum geometry rules was applied to the design of the cyclone, the equation for cyclones less than 1-in. diam. reduced to:

$$(\mathrm{GPM})f = 0.37\ (F)^{0.44}\ (D)^{1.8} \qquad (5)$$

Experimental equipment and method

Cyclone diameters chosen were 10, 20, 30, and 40 mm. Pyrex glassware was chosen because of the ease of fabrication involved and its ready availability. The glass cyclone also has a secondary advantage in that the surface roughness of the cyclone wall is kept to a minimum. The design of the cyclones themselves was made as much as possible in accordance with earlier established criteria for larger cyclones on the basis of exhibiting the sharpest classification at the smallest particle size for a given set of operating conditions (*5, 6, 14, 15*).

A brief summary of these geometric guides is as follows:

1. Cyclone included angle should be kept as low as possible consistent with headroom height. (In this investigation, 10 degrees).
2. The bottom of the vortex finder should be 6-in. or one cyclone diameter, whichever is less, from the transition point between the conical and cylindrical sections.
3. The vortex finder should extend just below the bottom of the feed inlet to the cyclones.
4. Inlet nozzle angle should allow the entering fluid to descend at least one inlet nozzle diameter in the first revolution. (In this investigation, 5 degrees).
5. Inlet, overflow or vortex finder dimensions are determined with respect to cyclone diameter according to the following equations.

$$\frac{2_f + o}{D} = 0.35 \text{ to } 0.70 \qquad (6)$$

$$\frac{o}{f} = 1.0 \text{ to } 1.6 \qquad (7)$$

6. Distance between the top of the inlet port and the cyclone top should be kept at a minimum to minimize secondary flows which result in over-all decrease in efficiency.

The top of the cyclones was adapted from standard laboratory rubber stoppers. Axial holes were cut through the rubber, concentric with the cyclone axis so that glass vortex finders could be inserted through the cyclone tops into the cyclone bodies. Because of the positive pressures, it was necessary to provide securing lugs to which stopper hold-down reinforcement could be attached. The four glass cyclones

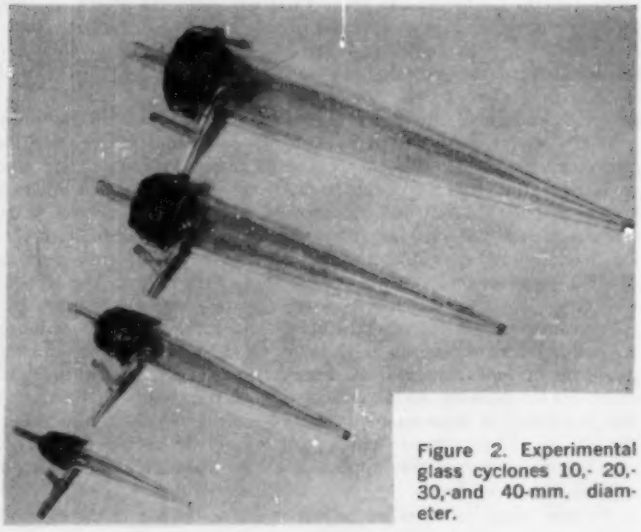

Figure 2. Experimental glass cyclones 10,- 20,- 30,-and 40-mm. diameter.

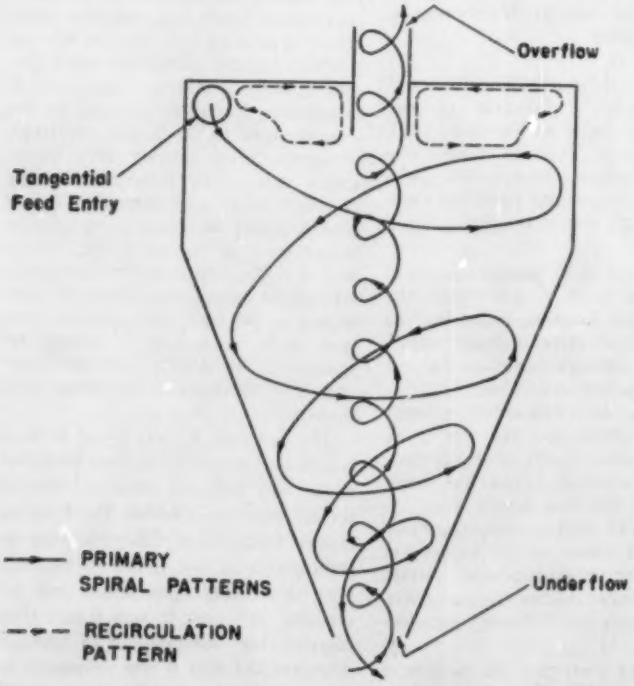

Figure 1. Major flow patterns in a liquid cyclone.

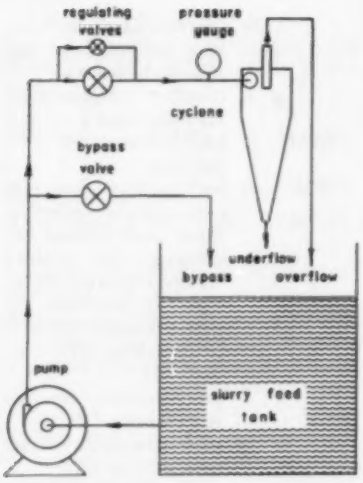

Figure 3. Diagram of experimental equipment.

are pictured in Figure 2. Static pressure taps were attached directly to the feed inlet to minimize the need for corrections due to loss of head in the small diameter feed nozzles. Figure 3 shows a schematic diagram of the entire experimental equipment.

As earlier work supplied a straightforward approach to energy requirements for liquid-solid cyclones of greater than 3-in. diam., an analogous approach for smaller cyclones was employed (5).

The general energy or capacity equation as given earlier is:

$$(\mathrm{GPM})_f = K(F)^a\,(of)^b \qquad (8)$$

Taking logarithms of both sides of the equation:

$$\log\,(\mathrm{GPM})_f = a\,\log F + \log K\,(of)^b \qquad (9)$$

It is evident that when the feed rate is plotted as a function of applied head on log-log paper, the results should be straight parallel lines with slope "a" and with parameters of (*of*) if the proposed capacity equation is correct for this extended cyclone size range.

In order to examine the small cyclones along the lines of the above equation, twelve runs were made over a range of twelve (*of*'s) covering all four cyclones. The feed rate for each (*of*) was varied by changing the feed pressure four times within a run. The overflow rate at each pressure was measured along with the underflow rate and combined to obtain the feed rate.

The medium used for all capacity runs as well as the solid elimination runs discussed in a later section was made up of an approximately 12% by weight slurry of a 2.74 specific gravity clay (98% minus 25 μ, 75% minus 6.5 μ) in water. On each of the four cyclones, three (*of*'s) were examined making a total of twelve (*of*'s).

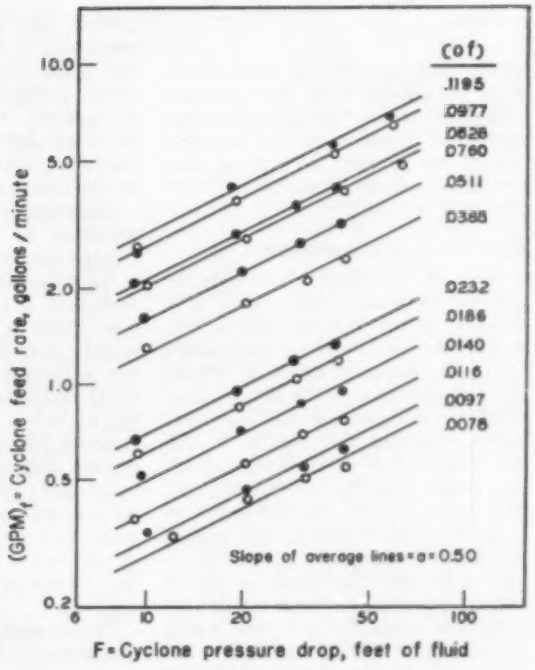

Figure 4. Cyclone feed rate vs. energy loss. Parameters of overflow X feed diameter.

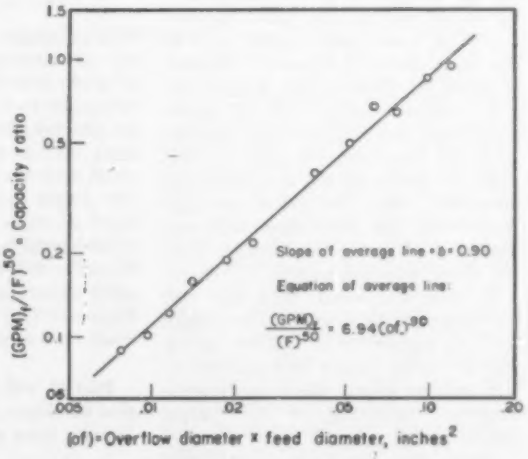
Slope of average line = b = 0.90
Equation of average line:
(GPM)f / (F)^.50 = 6.94 (of)^.90
(GPM)f/(F)^.50 = Capacity ratio
(of) = Overflow diameter x feed diameter, inches^2

Figure 5. Cyclone capacity ratio vs. overflow diameter X feed diameter.

Assuming that there is a satisfactory correlation of the above, a second plot of $(\mathrm{GPM})_f/(F)^a$ (capacity ratio) as a function of (*of*) on log-log paper should result in a single straight line with slope of *b* and an intercept of *K* if the capacity equation is to be substantiated completely. All the other variables that might effect capacity or energy requirements were set for optimum behavior as predicted by earlier work and are referred to in the preceding discussion.

Bernoulli's equation was applied to correct for kinetic head losses in both the overflow and feed lines as well as the static head difference between the overflow and feed lines. The head term, *F*, in the capacity equation is the net head difference between the overflow exit and feed entry.

It should be emphasized that total feed gallons per minute $(\mathrm{GPM})_f$ was used in the correlation rather than $(\mathrm{GPM})'_f$ as indicated in Equation (3). In the experimental work performed, highly thickened underflows were not produced. This was caused by the very fine size distribution of the clay

continued on next page

continued

solids employed in the test work. Most of the particles were present within or below the classification range and therefore entered into the energy loss through the cyclone. Accordingly, no correction to the feed rate was necessary.

Results and conclusions

As just discussed, feed rate in gallons per minute was plotted as a function of net applied head in feet of fluid for the twelve (*of*) parameters on log-log paper as shown in Figure 4. Average straight lines of slope +0.50 were drawn for the data points as they yielded the best fit. It will be noted that with three exceptions, agreement with the average straight line drawn is good. The first exception was one point at 9.20 ft. net applied head for the largest cyclone with an (*of*) of 0.1195. This could be due to either experimental error or the incomplete formation of a free vortex within the cyclone although the former is more probable. The other two exceptions are the two smallest (*of*) parameters (0.0097 and 0.0078 sq. in.) on the 10-mm. diam. cyclone. A line of lesser slope would have fit the data better. However, because of standard glass tubing sizes available, cyclone design did not agree completely with the accepted criteria given in Equations (6) and (7). Because of the excellent agreement experienced with the other ten (*of*) parameters, the same slope was employed in drawing the average lines for those two parameters.

It will be noted that one (*of*) parameter, 0.0628 sq. in., lies above the (*of*) parameter of 0.0760 sq. in. The deviation cannot be explained by the authors unless there were some improper centering of the vortex finder in the cyclone.

From the above, it is felt that exponent a on the applied head F in Equation (8) is 0.50. This of course agrees with the previously developed equation for larger cyclones as given in Equation (3).

The average straight lines drawn in Figure 4 were extrapolated back to $F=1.0$ in order to yield the average value of $(GPM)_f/(F)^{0.50}$. The resultant capacity ratio values were plotted against (*of*) in sq. in. on log-log paper as shown in Figure 5. An average line of best fit with slope = +0.90 has been drawn for the twelve data points. Again, good agreement is apparent. Average deviation of the twelve points from the line is ± 5.18%. If the datum point from the 0.628 (*of*) run is ignored, the average deviation becomes only ± 4.17%. As some anomaly was noted for this parameter previously in Figure 4, it should probably be ignored. It also exhibited the maximum deviation of 16.35%. The maximum deviation for the other eleven runs was only 7.24%.

Undoubtedly, much of the slight scattering for the data around the average line drawn in Figure 5 is due to the influence of volume split to the underflow. It appeared that high volume splits to the underflow would slightly increase capacity at the same net applied head. As volume split could be changed only by increasing the underflow opening on the glass cyclones which would result in permanent alteration, the necessary number of runs to obtain more quantitative information could not be made. However, as noted earlier, the average deviation was only 4 to 5% from the line drawn so that this influence is not large.

The equation of the average straight line drawn in Figure 5 is:

$$\frac{(GPM)_f}{(F)^{0.50}} = 6.94\ (of)^{0.90} \qquad (10)$$

This compares favorably with Equation (3) developed for larger cyclones of from 3 to 36 in. diam. The only deviation is in the K value which ranged from 5.5 to 6.5 for the larger units and is 6.94 for the 10-degree small cyclones employed in this work. The larger value may be due to the lesser included angle and the much smoother surfaces obtained with glass. However, it is felt that the good agreement experienced further strengthens Equation (10) and its application to small diameter cyclones.

Part II will consider solid elimination efficiency and will appear in the January issue of CEP.

NOTATION

a = exponent on F in Equation (8)

b = exponent on (of) in Equation (8)

C = proportionality constant in Equation (12) and (14)

d = particle effective diameter, ft.

d_{50} = equivalent diameter of particle reporting 50% by weight to both underflow and overflow streams, μ

D = cyclone I. D., in.

f = cyclone feed I. D., in.

F = applied head between feed and overflow nozzles, feet of fluid

g = effective acceleration, ft./(sec.)(sec.)

$(GPM)_f$ = feed volume flow rate, gal./min.

$(GPM)'_f$ = feed volume flow rate corrected for underflow solids slurry volume not entering into cyclone energy loss as per Equation (3), gal./min.

K = proportionality constant in Equations (3), (8), and (9)

K' = proportionality constant in Equation (1)

K'' = proportionality constant in Equation (2)

K''' = proportionality constant in Equation (4)

m = exponent on (*of*)

n = exponent on $(GPM)_f$

o = cyclone overflow diameter, in.

r = radius

V_t = tangential velocity

V_s = terminal settling velocity of particle, ft./sec.

Greek letters

a = exponent on radius involved in Equation (1)

ρ = specific gravity of fluid, g./cc.

ρ_o = specific gravity of overflow slurry, g./cc.

ρ_s = specific gravity of solid, g./cc.

μ = liquid viscosity, lb./ft.-sec.

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Industrial crystallization at Trona

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Crystallization in the Trona plant of the American Potash & Chemical Corporaton is practiced on a tremendously large and varied scale. In processing the brines of Searles Lake, more than 3,000,000 gal. liquor/day are evaporated to dryness (in a cyclic process) and the solids separated by a complex fractional crystallization procedure. More than 2000 tons of salable products (eleven basic chemicals*) and 2000 tons of sodium chloride are produced daily, requiring more than twenty-three separate crystallization steps.

Considering the size of the operation, the low unit price of the chemicals produced, and the highly competitive nature of the products, it is important to perform these crystallizations in the most efficient and effective manner possible. This has led to many studies of the crystallization unit operation and the development of a detailed technology on the subject. The plant crystallizers have evolved from rather crude equipment such as cooled tanks and the old calandria evaporator-crystallizers to modern-growth-type crystallizers specifically designed for each problem.

Because of the unique problems encountered with the complex mixtures of salts in Searles Lake brines, much of the technology had to be worked out on the spot without benefit of precedent. Perhaps more important, however, is the fact that crystallization has been one of the less studied and slower growing unit operations, and until fairly recently it has been much more an art than a science. For both reasons, extensive studies of crystallization have been necessary at Trona and have included exhaustive laboratory studies and pilot plant investigations. A number of the specific crystallization operations will be discussed with a review of some basic design principles.

Crystallization studies

Crystallizer design. Crystallization theory has not been developed to the point that it is as mathematically predictable as some of the other unit operations. However, the underlying principles of both nucleation and growth, as well as the factors influencing industrial crystallization, are fairly well known *(1)*. This can be of considerable help in a crystallization process design, but owing to the complexity of the variables involved, almost every design must actually be based upon specific small-scale tests with the liquors involved. These test data may be obtained in a number of ways, but first other more fundamental information is required.

A working knowledge of the solubility relations involved in the system under study is the first requirement, for the data will usually determine the details of the process and perhaps even the equipment to be employed. Solubility relations may be obtained from reference works in some cases, but it is usually best to at least verify the more important areas of the curves experimentally in order to be sure of the effect of impurities and cosolutes.

The second step in a study is to examine the specifications for the product as to crystal size, uniformity, and purity. If these are not fixed, some thought must be given to the acceptable range and to the extra price that can be paid for the better product. The general picture of economics must also be examined at this point to see what overriding considerations must be adhered to in the design, such as minimum capital cost, use of equipment at hand, etc. These two factors, economics and product specifications, will often be the most important aspects in deciding upon the type of equipment to be used.

Experimental tests should next be made on the system. These can be conducted with widely varying degrees of thoroughness, but the key point is that the final tests must be carried out in apparatus and under conditions that accurately simulate the large-scale equipment being considered. There is more flexibility in this requirement than might be expected, for plant conditions can often be correctly simulated in relatively simple equipment, but the experiments must be done carefully and knowledgeably. In general, the more complex and difficult the problem, the larger the pilot plant equipment required and the more extensive the laboratory study. Of course, the easiest course for such experiments is to conduct them in the test facilities of an equipment manufacturer, but this will serve only for fairly simple problems since ordinarily neither the time nor the equipment is available for long, complex studies. Therefore, in undertaking a study of this kind it is generally best to do as much screen-

continued

* $Na_2B_4O_7 \cdot 10H_2O$, $Na_2B_4O_7 \cdot 5H_2O$, $Na_2B_4O_7$, H_3BO_3, Na_2SO_4, Na_2CO_3, KCl, K_2SO_4, Li_2CO_3, H_3PO_4, Br_2.

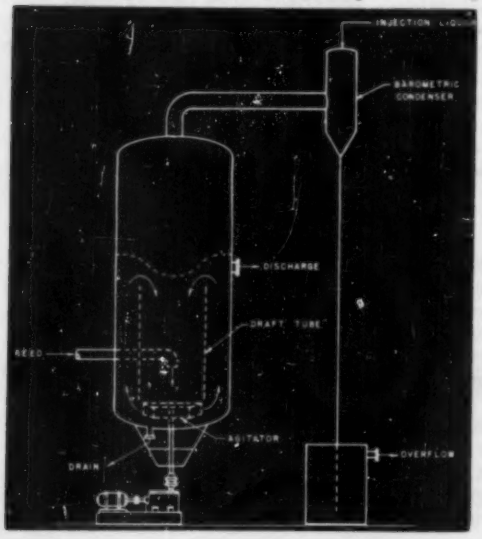

Figure 1. Pachuca-type forced circulation crystallizer.

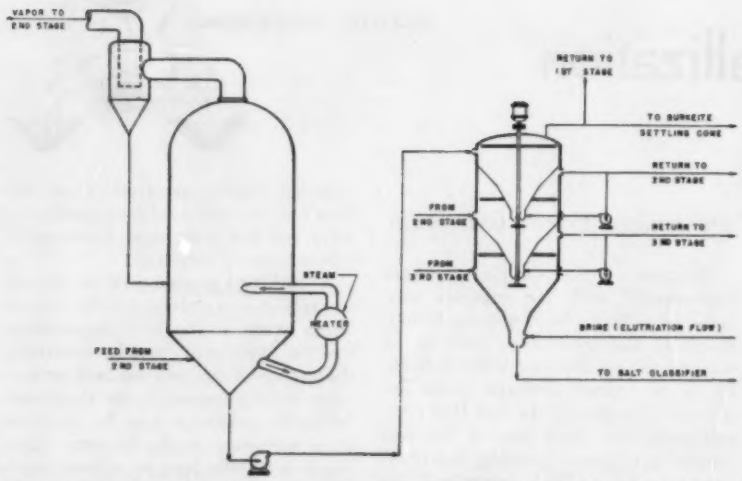

Figure 2. First stage and salt trap of brine evaporator-crystallizer. Triple effect —five heaters on each effect.

continued

ing of the variables as possible on a small scale, before moving to the less flexible and more expensive pilot plant. In pilot planting it is usually advantageous to avoid intermediate-sized equipment (2-50 gal. capacity, or less than 2- to 4-ft. diam. bodies) since these units are difficult to operate and control. Vessel and line salting can be a serious problem.

In making the final plant equipment design there are a number of useful guides to follow. First, in the majority of large continuous crystallization problems either forced circulation or growth-type forced circulation crystallizers are the preferred kind to use. They are the least expensive per unit capacity, occupy the minimum floor space, and offer the best control over the crystallization variables. Forced circulation units are used for easy crystallizations or somewhat flexible product specifications. Growth-type units are more expensive and are equal to more difficult crystallizations and demanding specifications. Either kind may be of the pachuca (Figure 1) or external circulation variety, the pachuca generally being favored because of its gentler agitation (less crystal breakage) and often less costly construction and operation. In many cases there is a choice between vacuum cooling and heat exchangers for the liquor cooling process. Vacuum cooling is usually strongly favored when possible, so as to reduce salting and fouling problems with the heater tubes, and downtime for washouts. Maintenance is also usually reduced.

There are many ways in which the crystallization may be regulated to turn out the desired product with the maximum time between washouts. The most important single feature, however, is the control of supersaturation so that nowhere in the process does it exceed the hypothetical supersaturation curve and allow "labile" conditions to exist, in which spontaneous nucleation occurs. Materials differ widely in the extent to which they can be supersaturated, and this is one of the chief factors to be determined in experimental tests. Usually, supersaturation is controlled by adjusting the feed rate, recirculation rate, and temperature changes so that the solution stays within the "metastable" zone. Other variables, the effective liquor residence time, and the sludge density, are generally somewhat more important to the relief of supersaturation, if it is a factor, than to supersaturation control *per se*. The point of feed injection and the boiling surface are most often the zones of extreme supersaturation, although recirculation pumps, agitators, and air leaks (creating foam) can also be troublesome. Many of these factors must be tested in the laboratory to determine their limitations, but good design practice can also eliminate some of them as problems.

The major distinction between growth-type crystallizers and conventional forced circulation units is the ability of the former to operate with a controlled (and increased) sludge density and to discharge both a comparatively clear overflow liquor and a thickened sludge product. Although this is an important feature, it generally cannot be carried to extremes, because increased attrition also accompanies increased sludge density and this may more than compensate for the improved supersaturation control. In some cases, however, this attrition becomes an important asset in itself, for it causes the agglomerates and fragile crystals to break, and often rounds the edges of the crystals sufficiently to form spheres or rice-shaped particles. If the amount of fragments and fines produced is not so great as to form an excessive number of nuclei, the net result can be good, for stronger, better shaped crystals may result.

Finally, there are a number of special design features that can be used to improve the crystallization, especially in the case of renovating an old unit. One that deserves special attention is the provision for removal of excess fines that may form. Under controlled growth conditions the number of nuclei formed per unit time must be equivalent to the number of crystals of the proper size withdrawn as product. If an excess forms, the desired product cannot be attained. One answer to an imbalance would be to continuously classify a portion of the circulating magma and remove the excess fines. These can be either discarded or redissolved and returned to the unit. Such a procedure can be highly effective in producing large crystals from a difficult solution or crystallizer.

Trona Crystallizers. The crystallization problems encountered at the Trona plant call for using most of the different methods of crystallizing salts from a solution. Instead of a discussion of types of equipment, therefore, a few examples of methods of crystallization will be reviewed, together with their attendant design and control problems. In the case of almost every Trona product, a uniform and specifically sized (usually large) crystal is desired. The reason may be merely ease in dewatering and wash-

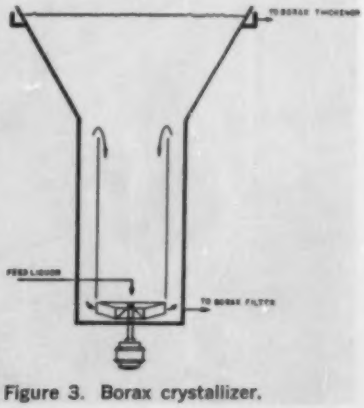

Figure 3. Borax crystallizer.

ing, or it may be rigid customer specifications.

Evaporation Crystallization. More than 5000 tons of salts/day are made in evaporator-crystallizers since included in this category are the main brine evaporators (2, 3). These units (Figure 2) consist of three-stage, counterflow, forced circulation, conventional (not growth-type) evaporators, operated with a separate solids removal and classification system. About two thirds of the water in the feed liquor (brine plus recycled evaporated and crystallized liquor) is removed on each pass through the evaporators, crystallizing out large quantities of sodium chloride and burkeite ($2Na_2CO_3 \cdot 3Na_2SO_4$), and some licons ($Li_2NaPO_4$) and sodium carbonate. Careful control is kept on the crystallizing conditions to insure uniform crystallization, since a hydraulic separation is made on the burkeite from the salt. The sodium chloride is predominately large (> 60 mesh), while the burkeite is small (100 to 200 mesh). Thus only a little burkeite is lost with the salt and only a small amount of salt contaminates the burkeite.

In an extensive large-scale pilot plant study of this process, the optimum design and process control were determined. One of the major problems was that of minimizing the salting of the external forced circulation heaters and the vaporizer section of the crystallizer. With the presence of two crystallizing salts with a reverse solubility, burkeite and licons, as well as the large quantities of sodium chloride, salts deposition is rapid and frequent washouts are required. It was found that such deposition could be greatly retarded by careful control of supersaturation. Factors such as high circulation velocity through the heater tubes, low temperature rise of the liquor passing through the tubes, and a high sludge density were important. Residence time in the crystallizer body and ΔT_{LM} across the heater tubes were of lesser importance.

Interestingly, it was shown that the major effect of sludge density in the tubes was to reduce fouling through attrition, or through a scouring effect on the tube walls. The increased density of either burkeite or sodium chloride aided the growth of larger crystals of that salt, but beyond a rather low limiting total concentration the burkeite attrition became so great that its crystal size was greatly reduced. Even though the solids separation was thus enhanced, the problems with settling and filtration became increasingly difficult for the fine burkeite. For best operation a compromise had to be reached between optimum relative crystal size of the two materials, and the control of salt deposition in the tubes. The possible range was a narrow one, but by close control a satisfactory operation was achieved in the large pilot plant unit.

Cooling Crystallization — Vacuum. The crystallization of potash provides an interesting example of vacuum cooling. The liquor used as feed to this plant, when cooled, is saturated with three phases, potassium chloride, sodium chloride, and borax. By rapid cooling and careful avoidance of borax seed crystals, the rather sluggish borax is prevented from crystallizing even though the solution is taken 35°F. below its saturation temperature. Sodium chloride is prevented from crystallizing by taking advantage of its solubility curve, which is rather flat compared to that of potash. Sufficient water is added to just prevent its being saturated at the terminal temperature, without seriously affecting the potash yield. A relatively pure potash is produced in this manner, and borax and sodium chloride are crystallized separately in two later stages of the process (borax in the next step by heavy seeding, and salt in the brine evaporators).

Use of vacuum cooling provides a convenient means of lowering the temperature most economically and efficiently. There are several liquors that can be used for heat exchange purposes in surface condensers, and others for use in barometric condensers. High heat transfer coefficients are realized in both types of equipment and, more importantly, scaling or salt deposition is not a problem. One further advantage of the barometric condensers is that if a liquor is used with a composition somewhat similar to that of the crystallizing liquor, the boiling point rises of the two cancel out, and a close temperature approach can be realized.

Cooling Crystallization—Circulation Coolers. A second type of cooling crystallizer is that in which the crystallizing liquid is circulated through a heat exchanger and cooled directly. Often this is done after an initial stage employing barometric cooling, one such case being Trona's sal soda coolers. In these, a brine rich in sodium carbonate but also saturated with sodium chloride and containing sodium sulfate is first cooled in two-stage vacuum-evaporative crystallizers to crystallize sodium chloride. The remaining liquor, now nearly saturated with respect to sal soda ($Na_2CO_3 \cdot 10H_2O$), is cooled in two stages to a

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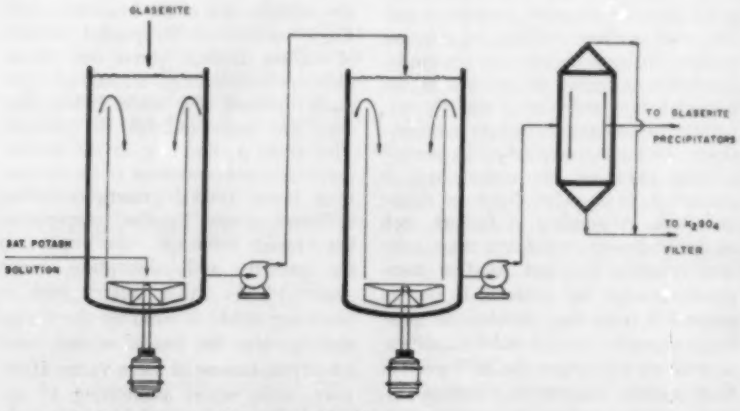

Figure 4. Potassium sulfate crystallization.

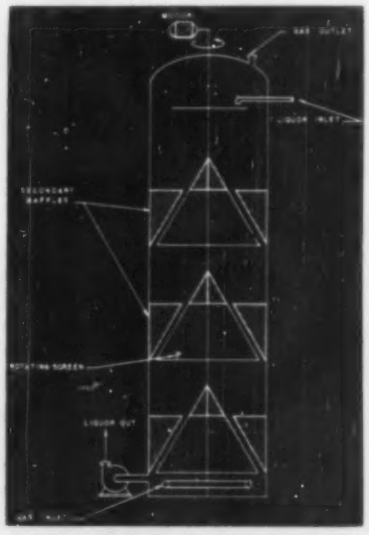

Figure 5. Carbonation tower—crystallization of $NaHCO_3$ from brine by the absorption of flue gas.

continued

temperature of about 40°F. by means of forced circulation ammonia-cooled heat exchangers. Relatively large sal soda crystals are easy to form in these units but the problems of fouling the heat exchange surface is a severe one. The customary factors of relatively high velocity through the tubes and low temperature drop of the liquor passing through the coolers are important. However, the most important single variable is that of the ammonia to liquor ΔT_{LM}, where at above 10° to 12°F. the fouling rate becomes greatly accelerated. As an interesting method of mitigating this situation, a number of tests have been made on the use in the coolers of polished stainless steel or plastic coated tubes. It was found that polished tubes and those made of certain plastics were quite effective in prolonging the period between washouts of the coolers.

Seeding Crystallization. Use of a controlled addition of seed crystals to initiate a crystallization is well known in the sugar industry. This technique can also be used effectively in a number of inorganic crystallizations. For instance, at Trona the careful addition of sodium sulfate to a saturated sodium chloride, sodium sulfate, sodium carbonate mixture allows the precipitation of sodium sulfate, even though the solution is well within the burkeite field. Careful control must be maintained of concentration, sludge density, and impurities, but a reasonably stable operation can result. It is a comparatively rare occasion on which the solution inadvertently becomes seeded with burkeite and the entire slurry converts to the stable burkeite phase. When this happens the system must be dumped, washed out, and the process started again.

A second example of a seeding crystallization is the precipitation of borax that follows the potash crystallization previously discussed. During the rapid cooling in the potash crystallizers no borax crystallizes, but when seed crystals are added to this cool filtrate, borax will come out. The rate of crystallization is proportional to the quantity of seed present, and a fairly reproducible family of curves can be drawn for the percent approach to saturation vs. time for various seed densities. Naturally, a high density is employed in order to minimize the size of the equipment. To handle this large amount of solids most advantageously, the gentle pachuca-type growth crystallizer is employed (Figure 3). Thus large crystals are formed at the same time that a reasonable approach to saturation is obtained.

Salting-Out Crystallization. In the foregoing example of precipitating sodium sulfate, the continuing driving force to crystallize the unstable salt cake was provided by adding solid phase sodium chloride to the solution. In this manner the sodium sulfate solubility was lowered from about 12 to about 7%, allowing a considerable crop to be produced. Considering the difficulty of adding just the correct amount of sodium chloride to give a nearly complete reaction without contaminating the product with salt, automatic and continuous sodium chloride meters are a vital part of the control on this process.

A second example of a crystallization similar to a salting-out reaction is the formation of a stable salt pair (the product) from an unstable reactant pair. One instance of this is the second step of the production of potassium sulfate from glaserite ($3K_2SO_4 \cdot Na_2SO_4$) and potassium chloride (Figure 4). By adding solid phase glaserite to a concentrated solution of potash, a conversion to the stable pair occurs, resulting in slightly soluble potassium sulfate and leaving Na_2SO_4 and KCl in solution. After filtering the potassium sulfate crystals, the filtrate may be returned to the glaserite precipitation step for further use of its sulfate and potash content. The potassium sulfate crystals produced in this process can be made surprisingly large and uniform by proper process control, probably because of the slow rate of solution of glaserite in the saturated potassium chloride solution.

Solid Phase Transformation. This caption is a misnomer, for in the industrial crystallizations to be discussed here, the one phase dissolves before the next crystallizes, but the net change and the observed result are that one phase changes to another. The conversion described above of solid glaserite to solid potassium sulfate and sodium sulfate in solution might be considered an example. However, a better illustration is the conversion of anhydrous sodium carbonate to sodium carbonate monohydrate. This is accomplished by merely adding soda ash to water, and is practiced to convert light to dense soda ash. A number of factors such as slurry density, residence time, solution temperature, and solution composition must be controlled, but in general it is an easy problem to grow large crystals. Crystal habit modification is an important factor here, for both sodium chloride and sodium sulfate, which are normally present, are active modifying agents. The presence of relatively large amounts of sodium sulfate helps to form large particles, but above about 3% burkeite may precipitate. Sodium chloride is also helpful up to a value of 4 or 5%, but, again, its presence lowers the burkeite solubility. By striking a balance between these limits an excellent product can be made.

These two examples of solid phase transformations are not typical of the majority of such crystallizations. Generally, fine crystals result from a rapid change from one hydrate form to another, or the change from a single to a double salt. In most processes such changes are carefully avoided. However, when the dissolution of one phase is slow, a fair degree of supersaturation can exist with the crystallizing phase, a good product can result, as in the case in these examples.

Crystallization by Chemical Reaction—Absorption. Most reactions resulting in precipitates are actually crystallizations, and all the factors that are important in crystallization control are important in the formation of the precipitate. An example of crystallization with chemical reaction is encountered in the absorption of carbon dioxide in brine, crystallizing out the relatively insoluble sodium bicarbonate. At the Trona plant, flue gas is used as the source of carbon dioxide and the absorption is carried on in 50-ft. towers containing three large rotating screens (Figure 5) (*4, 5*). The towers are kept full of brine, flowing down the towers countercurrent to the gas. The gas, entering at a relatively low pressure, is vented out the top.

This design, as is the case with most carbonation towers (including Solvay towers), is slanted primarily toward efficient absorption. However, control of particle size is also important in the operation since the crystals tend to be small and needle-shaped. Rather surprisingly, one of the most important single variables is the partial pressure of carbon dioxide; above one atmosphere relatively large crystals are generally formed (*6*), while below that they are more difficult to produce. The solution alkalinity, or the sodium carbonate concentration is also important, better crystal growth occurring at lower values. Finally, temperature has some influence, the optimum for growth and absorption being above 100°F. Other factors, such as recycling solids to build up the sludge density, and the use of crystal habit modifiers, can be of some value. However, even when attempting to optimize these many variables, this crys-

tallization, like most chemical precipitations, is difficult to control for ideal crystal shape and size.

Summary

The foregoing discussions cover briefly some of the crystallization technology of a large inorganic processing plant. In not every case is the crystallization practiced in its ideal form, for economics always enter strongly into the plant design and operation. This means that there must often be considerable flexibility in equipment capacity and versatility in operation. Also, it is often more economical to modify existing equipment for a given purpose than to purchase new equipment. Furthermore, to conserve time and the expense of investigation and design, standard designs are used whenever possible. The pachuca crystallizer, for instance, is nearly standard. It exists in many variations, of course, and other types are chosen for special problems, but because of its gentle agitation and low construction and operating costs, its general use is a major economy.

A somewhat standard investigation procedure, too, is generally used for the experimental studies invariably necessary to all new problems. Bench-scale equipment is the key to these studies, because it is rapid and inexpensive, and pilot plant tests can thus be shortened or, in many cases eliminated entirely.

The various crystallization processes may not always represent the ideal practice, but they often are, and considerable effort is made to make them always economical and efficient. The demands upon the crystallization unit operation are generally quite severe in this plant. Rigorous specifications should not add appreciably to the product cost, even though very often they are the prime factor in the product's salability. More and more the crystal's purity, size, shape, uniformity, and hardness are the deciding factors in the customer's acceptance of the product. With this trend, crystallization will certainly continue to be Trona's most closely studied unit operation.

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filtration

Analysis of Rotary precoat filter operation—new concepts

Part 1

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ROTARY PRECOAT filtration has made a substantial contribution to process engineering by making possible the filtration of materials which previously had to be handled by other means. While really an adaptation of the *continuous rotary filter*, it is generally more efficient than alternate procedures for separating mixtures that are difficult to filter. A thick precoat of filter aid (usually 2 in. or more) is applied to the drum before filling the filter bowl with slurry. As the filtration proceeds, a precision-mounted, highly sharpened, *doctor blade* is advanced at a fixed but adjustable rate of a few thousandths of an inch per revolution of the wheel. Deposited solids are removed along with a thin layer of precoat, thus continuously exposing a *fresh, permeable, filter-aid surface* to the slurry being filtered. Rotary precoat filtration had immediate acceptance for certain applications, particularly where filtration was impossible or where prohibitive amounts of filter aid in the batch would otherwise be required to insure filterability. Notable early users were the corn sugar industry for the filtration of starch conversion liquor, and the titanium dioxide pigment industry for the filtration of acid digestion liquors. More recently the largest users of this type of filtration have been in the antibiotics industry for the removal of mold micella from fermentation broths. Other current applications include leach liquors, refinery slop oil emulsions, lube oil additives, vegetable oils, and beer.

The earliest reference known to the authors on rotary precoat filtration, the patent application filed by Henry A. Wienecke *(1)* on July 5, 1933, describes the application and subsequent removal of the precoat filter layer in much the same manner as it is done today. Subsequent patents by August J. Barnebl *(2)* and Edward C. Ditzen *(3)* were concerned with improvements to the process, primarily in the manner of doctoring off the accumulated slimes and thin layer of filter aid. Ditzen's mechanism, which provides for both radial and lateral movement of the knife, is still in use today.

Motivation for this work. Wishing to determine the relative utility of various filter aids in rotary precoat filtration, the literature was searched for information on the interpretation of rotary precoat filter operating data. Little was found. Articles were written by Cummins and Morris *(4)*, and Schmidt and Harrison *(5)* shortly after the invention of the precoat filter. Some consideration was given to the more important variables involved in operating the rotary precoat filter, and while some of the facts presented could be challenged, both papers are to be commended considering the state of the art at the time of publication. More recent information on the use of precoat filters for the handling of refinery waste has been reported by Weston, *et al. (6, 7)*, Camp and Phillips *(8)*, and Alciatore *(9)*. Weymouth and Montgomery *(10)* reported a labo-

continued

Rotary precoat filter

continued

ratory study of rotary precoat filtration of phosphate defecated cane sugar affination syrup, and Halvorsen *(11)* described tests on the precoat filtration of paper-mill white water. Several other papers have dealt with rotary filtration but not with rotary precoat filtration. Our investigation was directed toward ferreting out and evaluating the various factors involved in rotary precoat filtration, with emphasis on interpretation of data and use of such interpretation in establishing optimum filtering conditions.

Such a study not only provides the basis for comparison of filter aids but also gives the industrial filter operator a method for establishing the best possible operating conditions.

Operating variables. This study of the rotary precoat filter was begun by listing the variables involved and then deciding which ones were most important to the investigation. The following were considered: 1. *type and grade of filter aid used in the precoat*, 2. *drum speed*, 3. *knife advance rate*, 4. *vacuum*, 5. *filter medium*, 6. *temperature of feed*, 7. *submergence*, 8. *manner of precoat application*, 9. *sharpness of knife*, 10. *knife angle and bevel*.

Slurries used were maintained as nearly as possible at the same filterability and the observed data corrected to exactly the same *filterability*. The effects of such operating variables as vacuum (ΔP), the temperature of the feed, and type of filter medium were minimized by selecting *standard conditions*. A light cotton twill filter cloth was used in all experiments. Selection of the proper filter aid is considered to be very important to the rotary precoat filter operation. The analysis given later shows how one may determine which filter aid performs best. A standard procedure used for precoat application will be described later. Knife advance, sharpness, angle, and bevel are undoubtedly related to the effectiveness with which accumulated solids are removed from the precoat cake. Presumably the best values of knife angle and bevel were incorporated into the filter design and no attempt was made to change these items. Removal of slimes was found to be a function of the *peripheral speed* of the filter drum. However, most runs were made at 1 rev./min., a speed at which cutting is usually satisfactory.

In general, the drum speed should be the maximum consistent with having the cake dry before it reaches the knife. The sliming of the surface was found to take a relatively short time, and submergence times greater than 15 or 20 sec. usually are unnecessary. With slurries which form cakes having appreciable permeabilities, greater over-all economy is achieved with a slower rate of rotation, since filter aid consumption is reduced by slower rotation of the drum, assuming that the knife advance and drum rotation are interlocked, as is the case with most industrial filters. Several industrial applications are known in which the drum rotation is as slow as 20-30 min./rev. There is some question, however, as to whether or not such an application of the rotary precoat filter can be fully justified. Submergence should be the maximum consistent with the cake drying fully before reaching the knife. Submergence was maintained at 45%.

Equipment and test procedure

Full details on this phase of the work have been registered with the ADI, see page 76 for particulars. Hence, only a brief description is given here. Initial studies were made on an 18-in. diam. by 12-in. face pilot plant rotary precoat filter unit but due to technical difficulties inherent in the size of the filter drum, a unit of a 36-in. diam. and 6-in. face was used more satisfactorily.

Precoats were applied from 1.75 wt. % slurries at drum speeds of 90-150 sec./rev., depending upon the filter aid being used. The form vacuum was started low and allowed to increase as cake built up. After formation, the balloon-shaped cake was trimmed to a trapezoidal cross-section of *constant face area*. Volume of precoat cake removed is directly proportional to knife travel, regardless of the position of the knife. This fact is particularly useful in determining cake density. For most of the work, 0.5 % aluminum hydrate was used as the test slurry. Since this material could be dissolved away with acid, direct measurements of precoat cake density were made. Other experiments were carried out using more difficultly filterable 2% swelling bentonite slurry at *p*H 11.

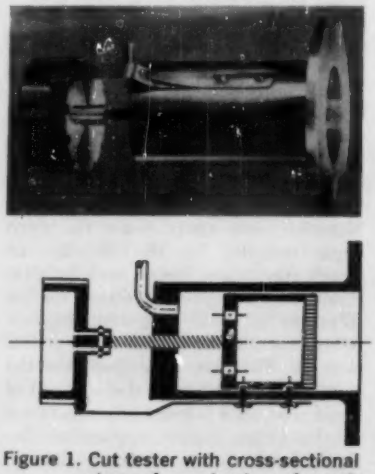


Figure 1. Cut tester with cross-sectional view of mechanism for advancing cake.

Other equipment included (1) a 0.1 sq. ft. test leaf obtained from Multi-Metal Wire Cloth Company *(12)*, to determine the permeability of thick filter cakes, (2) a Dorr-Oliver *(13)* 0.1 sq. ft. molded plastic leaf to determine filterability, and (3) a 24.2 sq. cm. rotary precoat test leaf—the Celite cut tester—for use in several experiments. Figure 1 shows construction details for this piece of equipment.

Test data and analysis

Cake structure and properties. The manner in which the precoat filter cake is formed produces a laminar structure (see Figure 6, upper right). Deposition during one revolution of the drum is governed by septum type and condition, by pressure drop (ΔP) available, and by permeability, drainage characteristics, filter-aid type and volume concentration. Variation of any of the foregoing factors will produce changes in the individual layers comprising a precoat filter cake, and an almost infinite number of combinations can be encountered in the formation of precoat cakes. Experiments were designed to provide filter cakes having maximum cutting economy with minimum cutting difficulties.

Experience has demonstrated that although the type of septum may be important, its condition with regard to cleanliness is equally so. A *differential analysis* indicated that as much as 35% of the total resistance of a system consisting of 2 in. of filter aid on a septum could come from the *septum* and the *filter aid-septum interface*. Reduction of this resistance would improve precoat formation generally, and this should be studied more fully.

The laminar structure of the precoat cake, and particularly the structure within the individual laminae, are responsible for a number of interesting operating phenomena. As the cake passes over the top of the wheel in the drying cycle, it is purged of liquid to some extent by air. As the

purged cake re-enters the slurry pool, liquid rushes in depositing a relatively open, permeable cake. As the cycle proceeds the cake becomes saturated, the liquid velocity diminishes, and material of lower permeability is deposited. This less-permeable cake emerges from the slurry pool, and is redried to repeat the cycle. As the cake on the filter becomes thicker, resistance to flow of liquid increases. Through a decrease in the vacuum supply or through the building of a cake of maximum or nearly maximum thickness, it appears that the outer layers of the cake become loosely held, and small sections of cake may actually fall off while the wheel is submerged. Some areas as great as 2 in. diam. loosen, but do not actually fall. Pockets are thus created which, on reentering the liquid, collapse. This is called *blistering*. With a built-up cake, decreases in vacuum of as little as 0.5 Hg can cause severe blistering. Some materials which form precoats with more pronounced laminae are more subject to blistering.

The manner in which various materials are cut by the doctor blade is related to the speed of approach against the knife, as well as the cutting characteristics of the materials themselves. Some materials chip, others pit, and still others tend to be scraped or scooped off the surface of the cake. Any chattering of the knife or vibration of the filter drum accentuates unfavorable cutting characteristics. For example, chipping on the larger experimental unit was traced to drum vibration. This is clearly shown in Figure 2. Similar vibrations have been noted in commercial filters in field operation.

Shrinkage may be defined as compaction of the cake radially. Similarly *cracking* may be defined as shrinkage of the cake laterally to an extent great enough to cause parting.

Data from actual filtration operations. Figures 3a and 3b illustrate differences in the surface condition of filter cake which so far as could be determined may be attributed only to the differences in rotational speed of the filter drum. Similar differences were encountered with other filter aids. Some of the finer materials cut satisfactorily at 6 to 7 ft./min., but cut less satisfactorily at 4.5 to 5 ft./min. With industrial filters, particularly with 8-ft diam. and over, the chances of operating at less than 6 to 10 ft./min. peripheral velocity are considerably reduced, but investigation is warranted when poor filter aid cutting is encountered. Sharpness of the knife will also affect the velocity required.

Table 1

Liquid permeabilities of Celite filter aids

Filter Aid	Water Permeability (Darcies)
Standard Super-Cel	0.22
Celite 512	0.44
Hyflo Super-Cel	1.1
Celite 503	2.3

Figure 4 graphically presents results for a filtering cycle at a *single rate of knife advance*. Note that as the filter cake decreases in thickness there is a corresponding increase in the filtration rate. This is typical for a substantial number of filtering cycles which were run with a variety of filter aids, a variety of rotation rates, and various rates of knife advance. Figure 5 is based on data from three such runs for a single material, an expanded perlite filter aid, at different rates of knife advance. As the rate of knife advance is decreased there is a corresponding decrease in flow rate. There is also a change in the slope of the flow rate curve when plotted with respect to thickness. This again is typical. Data were kept of the weight of filter aid actually removed from the wheel by the method noted earlier. From the filtrate volumes and filter aid weights, gallons of filtrate produced per pound of filter aid used can be calculated directly.

Figure 6 pictures the three runs plotted in Figure 5 and illustrates progressive loss of filtering capacity with decreasing rate of knife advance. A method by which the optimum rate of knife advance could be determined with a minimum number of filtering cycles was sought. A filtration cycle as described above was set up; then a series of cake fractions was cut at different rates of knife advance while recording the amount of filtrate from each fraction and the amount of recovered filter aid. In a few cases a second cycle was run with the same filter aid, repeating the final cut of the previous cycle, and then carrying the rates of knife advance to still lower levels. Figure 7 shows a typical plot for such a pair of runs. The flow rate data with the calculated yields from these two cycles can be replotted, as shown in Figure 8. Here the left ordinate represents gallons of filtrate per square foot per hour while the right ordinate represents the yield in gallons of filtrate produced for each pound of filter aid cut from the cake. The abscissa is in terms of rate of knife advance in mils per minute (also per revolution in this case). Figure 8 demonstrates that the raw

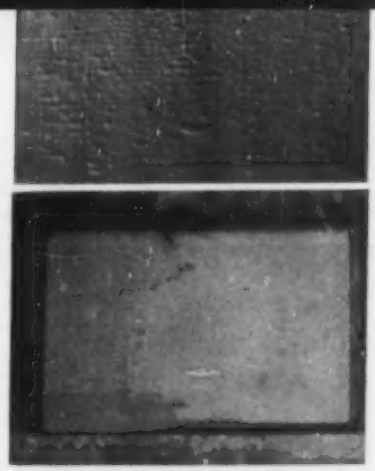


Figure 2. An example of effect of vibration on cutting and particularly chipping. Rate of drum rotation is 1 rev./min. which governs frequency. Here Celite 503 is filtering 0.5% $Al(OH)_3$. (Top) Cake before passing knife. (Bottom) After passing knife.

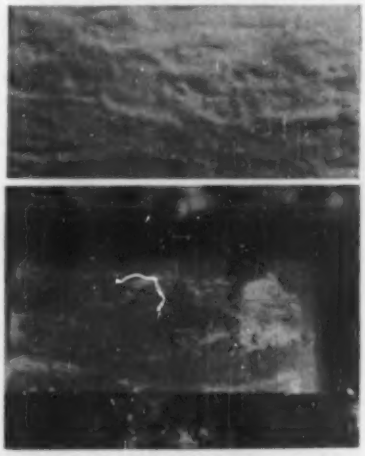


Figure 3a. Celite 503 precoat filter cake; filtering 0.5% $Al(OH)_3$ suspension; drum rotation rate 90 sec./rev. and knife approach speed 6.6 ft./min. (Top) Before passing knife. (Bottom) After passing knife.

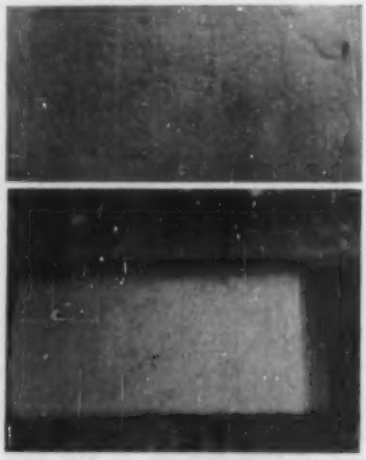
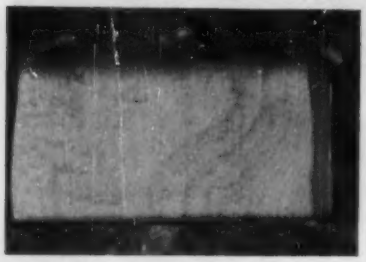
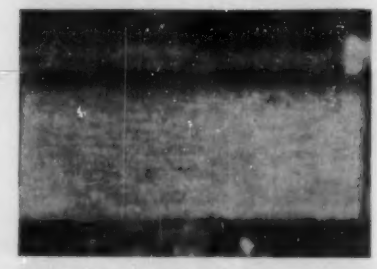


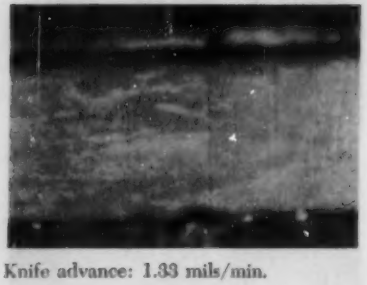
Figure 3b. Same as above except that rotation rate has been increased to 60 sec./rev. or 10.0 ft./min.



Knife advance: 3.00 mils/min.



Knife advance: 1.80 mils/min.



Knife advance: 1.33 mils/min.

Figure 6. Above pictures from three successive filtering cycles of Figure 5 illustrate progressive loss of filtering capacity of the cake with decreasing rate of knife advance. In each case the (top) picture shows cake before passing knife, (bottom) after passing knife.

Rotary precoat filter

continued

data obtained during cutting of a particular fraction, as shown in Figure 7, cannot be used without some sort of correction for thickness of the cake. The slope for the fourth fraction of Run 112 in Figure 7 is such as to indicate that stability of operation probably had not been reached, and this also may be reflected in the displacement shown by these same data in Figure 8.

It became apparent that factors other than thickness of the filter aid cake were also having substantial effect on the rate and yield values. Several attempts made to apply simple numerical corrections for the offset noted above, and at the same time insure that the flow rate would be zero at the time of zero knife advance, were unsuccessful. If worked out for a 90 sec./rev. run, corrections were not applicable to either 60 or 120 sec./rev. runs, and vice versa. It was decided to undertake a more critical analysis of the filtering cycle.

Analysis of the Filtering Cycle. Figure 9 represents a precoat filter with cake in place. A is the point of entrance of the cake into the unfiltered slurry and B is the point of emergence. C is the point at which the cake, together with its accumulated slimes, reaches minimum permeability. Greatest filtration economy can be achieved with exactly the right combination of depth of submergence and rate of rotation so that B and C coincide. If minimum permeability has not been reached before C reaches location B, the wheel is rotating too rapidly or the submergence is too low and part of the capacity of the filter aid is wasted. Conversely, if minimum permeability is reached before C reaches point B, either the submergence level could be lowered or the wheel rotated at a faster rate. Choice of decreasing the submergence level or increasing the rate or rotation would be dictated by the time requirement for the drainage of accumulated filtrate from the filter cake. In accordance with this thinking, if point B and C coincide with 50% submergence and 60 sec./rev. drum speed, a reduction in drum speed to 90 sec./rev. would move point C back to C_1 and a further reduction in drum speed to 120 sec./rev. would locate it at C_2. If the blinding medium has zero effective permeability, the filtrate collected under these circumstances should have a linear relationship to drum speed. However, if the blinding medium has appreciable permeability, additional filtrate will be collected in proportion to that permeability through the distances BC_1 and BC_2 for 90- and 120-sec./rev. speeds respectively.

With the Celite cut tester, 0.5% aluminum hydrate suspension was filtered through several different filter aids. The results are plotted in Figure 10. The vertical axis shows milliliters of filtrate collected; the horizontal axis, seconds of submergence followed by a 30-sec. drainage period, after which it was found that no additional filtrate was being carried over. Liquid permeabilities of the same Celite filter aids are shown in Table 1. While somewhat larger volumes of filtrate are collected for the higher permeability filter aids, note that the additional amounts are small relative to permeability. The time required to reach minimum flow rate is surprisingly consistent for the wide range of filter aids shown. One exception is relatively low flow rate Celite 512. After minimum flow rate is reached, these curves do not become parallel to the horizontal axis. The slopes are almost identical and represent residual flow through the blinding material, 6.6 gal./sq. ft./hr. at 15-in vacuum.

This is an oversimplification as actually the flow through the thin film of aluminum hydrate follows the

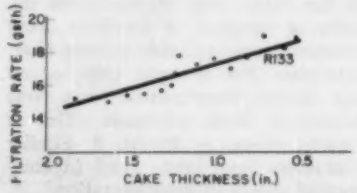


Figure 4. Performance of Celite 503 relative to cake thickness filtering 0.5% $Al(OH)_3$ suspension at 1 rev./min. and 1 mil/rev. (min.) knife advance.

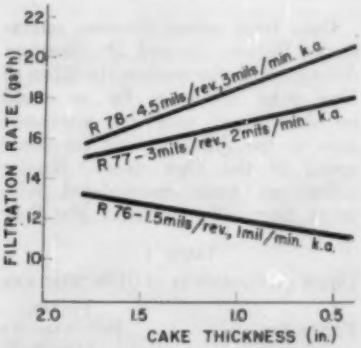


Figure 5. Performance of a typical Perlite filter aid relative to knife advance and cake thickness filtering 0.5% $Al(OH)_3$ at ⅔ rev./min.

usual filtration rate equations for compressible cakes, as evidenced by the slight downward curvature of all four plots. However, in this instance the elapsed time is so short that the permeability value for a very thin film is adequate. Thus, any combination of circumstances in which a *film* of aluminum hydrate develops, for example, low rate of rotation or inadequate removal of the previously formed film by the slowly advancing knife, will still allow appreciable filtrate production to the extent just noted. This would explain why the curves on Figure 8 appear to intersect the vertical axis above the origin, one of the less desirable features of aluminum hydrate as a test slurry. For this study, however, the disadvantage was more than offset by the need to recover the filter aid and obtain actual yield figures. Tests of the type shown in Figure 7 can be used for screening various filter aids to determine approximate submergence times and rates of rotation.

Although the previous discussion establishes the permeability rate of a totally blinded cake, it does not establish the proportion of the time in which the cake was totally blind in various operations. To evaluate the performance of the filter aid itself, it is necessary to separate the effects of the permeability of the filter aid and of the blinding medium. Figures 4, 5, and 7, in which filtration rates were plotted against thickness of the remaining cake, show that with more rapid knife-advance rates, filtration rate tends to increase with decreasing cake thickness, but that with shallow cuts: (1) the line may be displaced only downward with relatively little change in slope, or (2) the slope of the flow rate line may be changed and even become negative indicating decreasing filtration rate with decreasing cake thickness. Consideration will be given to the mechanism of each of these conditions.

A good starting point for the interpretation of filter data is the modified Darcy equation:

$$Q = \frac{K A \Delta P}{\mu L} \qquad (1)$$

where Q is filtration rate, K is constant, A is filtering area, ΔP is regulated pressure drop, μ is viscosity, and L is thickness of the filter cake. In the present experiments, K, A, ΔP, and μ are all constant, leaving Q proportional to $1/L$. This inverse relationship indicates that every time the cake thickness is decreased by half, flow rate will be doubled. The upper curve in Figure 11 shows this ideal reciprocal relationship based on a flow rate of unity through a 2-in. cake. Actually, the resistance to flow in a precoat filter or in any filter is derived not only from the cake of filter aid, but also from the filter septum and the filter aid-septum interface. Experimental evidence (see previous Section on *Cake Structure and Properties*) indicates that as much as 35% of the total resistance of a 2-in. cake of filter aid may be due to the septum and interface. Since this resistance is not decreased as the thickness of precoat cake decreases, it becomes a proportionately larger part of the total remaining resistance. The lower curve is plotted from experimental data obtained with the 3 × 0.5-ft. filter. This septum-interface resistance may differ from precoat to precoat, its value depending upon such factors as cleanliness of septum, compatibility of filter aid with septum, concentration of precoat slurry, initial rate of precoat formation, etc. The curves of Figure 11 deal with the filtration of solids-free liquid in which case no impairment of the filtering surface takes place.

Figure 12 shows the data of Figure 11 plotted vs. L rather than $1/L$. In this plot the area under the curve has a special significance. The X-axis is a linear function in time when rate of knife advance is constant. Total output of the cycle is proportional to the area under the curve from L = 2.0 to L = 0.5-the limits of L under investigation. Thus:

area = rate × time = output (2)

Practically, however, the slurry filtration rate realized is only a fraction

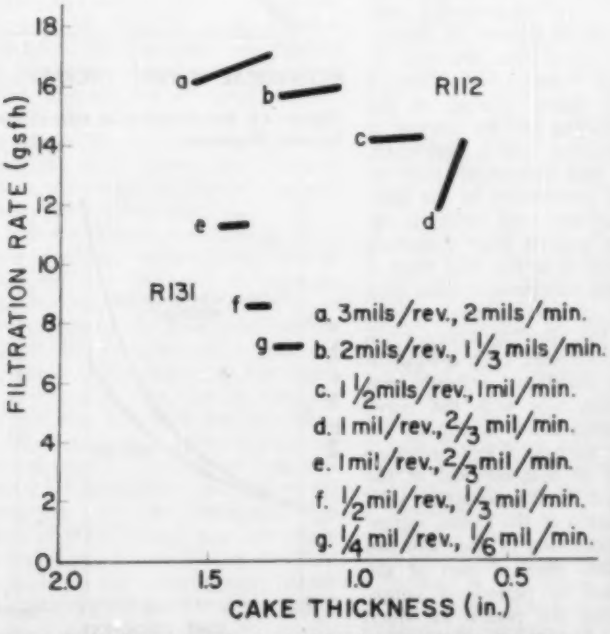


Figure 7. Performance of a typical fresh water diatomite filter aid relative to knife advance and cake thickness filtering 0.5% $Al(OH)_3$ at 2/3 rpm.

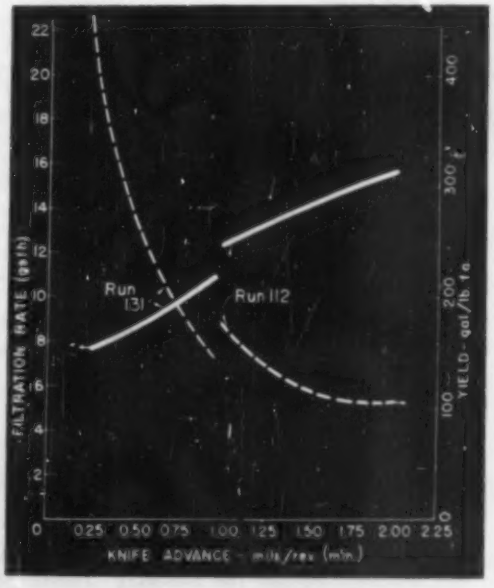


Figure 8. Performance of a typical fresh water diatomite, filter aid rate and yield vs. knife advance, filtering 0.5% $Al(OH)_3$ at 2/3 rpm.

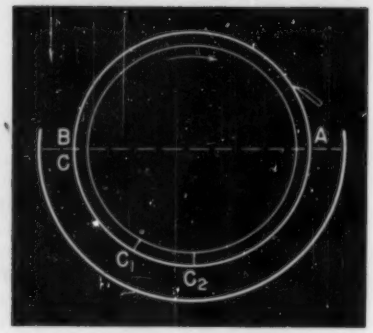


Figure 9. Schematic cross section view of a precoat filter.

Rotary precoat filter

continued

of that obtainable with solids-free liquid. Figure 13 shows a typical Q vs. L control plot (EF) compared with the theoretical performance of the filter aid with clear liquid, based on the permeability of a 2-in. cake, and neglecting septum resistance. This, while setting up a standard which never can be attained, gives a realistic basis for comparing two filter aids of similar permeability. Since the areas under the curves are proportional to total output of the cycle, the observed output (CDEF) is much lower than that theoretically obtainable with clear liquid (ABCD). If we arbitrarily call the filter aid 100% rate-efficient when operating with solids-free liquid under ideal conditions, then the rate-efficiency with the slurry involved may be calculated.

$$\text{rate efficiency, \%} = \frac{\text{area CDEF}}{\text{area ABCD}} \times 100 \qquad (3)$$

The curve AB is mathematically of the form:

$$Q = a\frac{1}{L} - b \qquad (4)$$

where a and b are constants. Hence, it would be possible to derive the equation for the line AB and compute area ABCD by integration. A much simpler solution, however, is to draw the equivalent straight line AB′ so that the shaded areas are equal. Then rate efficiency is readily calculated as:

$$\text{rate efficiency, \%} = \frac{\text{area CDEF}}{\text{area AB'CD}} \times 100 \qquad (5)$$

In Figures 11, 12, and 13 the plots have been limited to values of L between 2.0 and 0.5-in. This choice was arbitrary but for the following reasons: 2 in. is near the maximum thickness of precoat that can be applied with filter aids of moderate permeability; and, as is evident from inspection of Figure 12, Q begins to rise quite rapidly at 0.5-in thickness. All work and calculations are based on this 2.0- to 0.5-in. precoat range.

A further simplification may be made. Note that in Figure 13 the center of the cake used is at 1.25 in. Hence, areas AB′CD and CDEF may be calculated by multiplying the intercept of the diagonal line AB′ or EF times the base CD. Thus:

$$\text{rate efficiency, \%} = \frac{\text{no} \quad (CD)}{\text{mo} \quad (CD)} \times 100 \qquad (6)$$

Eliminating CD we have:

$$\text{rate efficiency, \%} = \frac{\text{no}}{\text{mo}} \times 100 \qquad (7)$$

This simplified procedure can be extended to all the efficiency calculations in this paper. The location of line AB in Figure 13 can be determined for any filter aid from its permeability.

Effect of Surface Blinding. Assume a precoat filtration in which the rate of knife advance is adequate to remove all the blinding surface layer and any penetration which has occurred during submergence. For any given filter aid, rate should approximately parallel the theoretical curve under these conditions. The magnitude of the rate is determined by the filtrate volume vs. submergence relationship shown in Figure 10. Permeability and type of filter aid, and the nature of the material being filtered each have a major bearing on the degree of blinding and the amount of deeper penetration into a filter cake.

It is less well understood that expansion and contraction of the filter cake itself are also vital factors in rotary vacuum precoat filter operation. If the filter aid is so fine that there is no penetration into precoat cake, then the slimed surface is said to be blinded. If this blinding layer is completely removed with each revolution of the drum, the filtration should proceed in accordance with the curve previously established in Figure 10. If, however, the rate of knife advance is decreased so that removal of the blinding layer is not complete with every revolution of the drum, expansion and contraction of the cake can result in 100% removal part of the time, followed by periods of nonremoval. During the period in which the knife is taking a full cut, filtration proceeds at the maximum rate, but during the noncutting periods filtra-

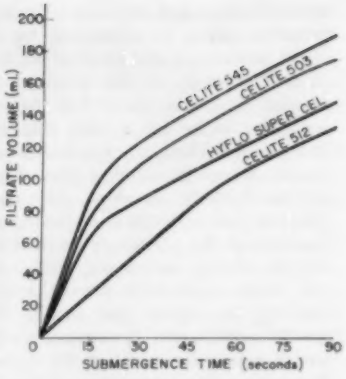


Figure 10. Relationship of submergence time to filtrate volume collected, filtering 0.5% $Al(OH)_3$ through a 1 in. cake on the Celite cut tester (24.2 sq. cm. area).

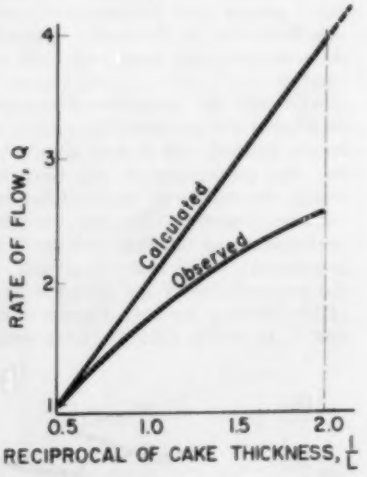


Figure 11. Relationship of rate of flow to cake thickness.

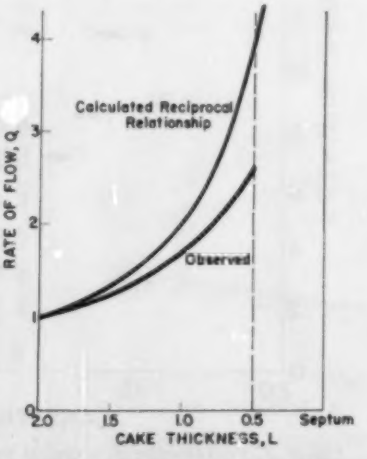


Figure 12. Relationship of rate of flow to cake thickness.

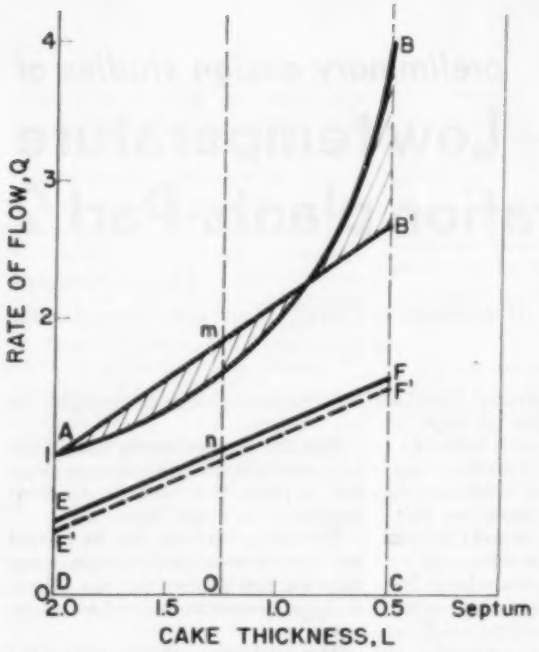


Figure 13. Relationship of blinding losses to theoretical efficiency.

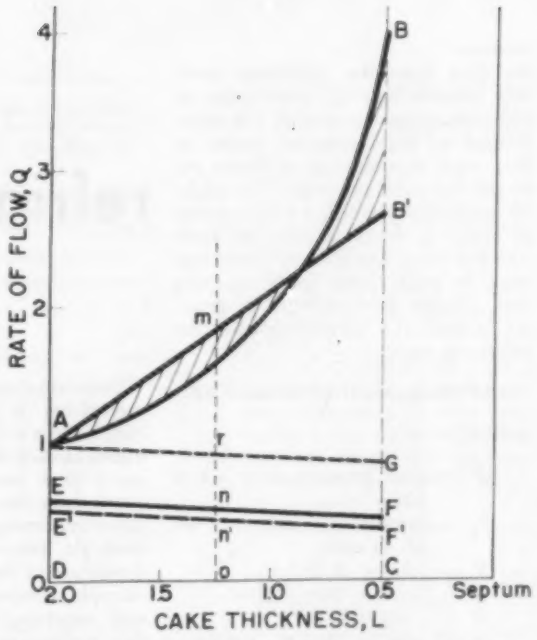


Figure 14. Evaluation of filter aid efficiency and blinding and penetration losses.

tion is reduced to the rate represented by the permeability of the blinding layer. This combination of circumstances results in a filtration-rate curve approximately parallel to, but displaced downwardly from, the theoretical curve as shown graphically in Figure 13. Observed Q vs. L plots are remarkably linear. This is evidence that the resistance of the filter aid cake plays only a minor part in restricting the flow of liquid through the filter. If the total area ABCD under the theoretical curve represents 100% filter aid rate efficiency and the area under the observed curve EF represents the performance attained, then the area above the observed curve represents the loss of rate efficiency due to blinding.

Effect of Penetration. The previous discussion has assumed that loss of filter aid rate efficiency or capacity was due only to blinding and that no penetration of the filter cake has occurred. If the nature of a filter aid is such that penetration of fine solids is continually occurring to a depth beyond that to which the knife cuts, a different situation prevails. Now the loss in capacity, and hence rate efficiency, is cumulative rather than intermitten with the result that the slope of the observed flow rate curve is decreased. Figure 5 is an excellent example of this phenomenon, where reducing the cut resulted in decreased slope.

Combined Effects. In actual practice, blinding and penetration are seldom encountered as separate effects, so the observed curve will probably have both angular and vertical displacement downward from the theoretical curve. With the location of such a curve known, a graphic evaluation of the rate efficiency together with applicable permeability corrections for the blinding medium can be made as in Figure 14. (See following section on Efficiency Calculations.) Here the total area under the theoretical curve AB′ represents 100% rate efficency; the bottom block under the observed line, EF, represents the filtration rate efficiency of the filter aid proper; the middle block represents the loss of capacity of the filter aid due to blinding, and the top triangular portion represents loss of capacity of the filter aid due to penetration of solids continuously into the cake beyond the cutting depth of the knife. Filter aids vary widely in their penetration characteristics, particularly among materials of different basic types. Shallow penetration, which has the effect of stopping deeper penetration until it can be removed by subsequent action of the knife, should be classed as blinding and not as penetration in the above descriptions. It has been found that even though such a blinding layer is of substantially greater thickness, it is still subject to approximately the same permeability correction as is observed with filter aids for which almost no shallow penetration has occurred to increase the thickness of the blinding layer. This explains some apparent anomalies in the application of the method of analysis in which filter aids having widely different penetration characteristics, i.e., both deep and shallow penetration, are being compared. A material which suffers from serious surface penetration appears to have substantially more blinding than a material which is not subject to surface penetration. Combined surface penetration and blinding limit deep penetration, and the slope of the line and relative proportions of efficiency-loss to blinding and penetration are thereby affected. Filter aid rate efficiency will probably be low under these circumstances.

Heavy shallow penetration is apparent immediately when the depth of cut required to produce adequate filtration rate and over-all filtration rate efficiency is considered. When surface penetration has occurred, a cut of two or three times greater depth is frequently required for a given rate of filtrate production than is required in the case of filter aid without such penetration, assuming similar liquid permeability. In the light of this theoretical analysis it can be seen that it would be readily possible to compare the filtration cycles shown in Figures 4 and 5, in which full cycles at a single rate of knife advance were made. It is equally evident that similar comparisons cannot be made for the series of short cuts illustrated in Figure 7. The results expressed in this graph are valuable from a screening standpoint, but it would not be correct to make critical comparisons of

continued

continued

the data from the individual short cuts because they are inadequate to definitely locate the over-all rate curve relative to the theoretical curve. In field work the number of cycles required for filter aid evaluation might be substantially reduced with a group of cycles in which a series of short cuts was made, but ultimate evaluation must be made from additional long cycles under the conditions of greatest interest as established by the screening work.

Part 2 will appear in the January CEP.

NOTATION

ΔP = total pressure drop across filter
P_s = mechanical pressure in solids in cake
V = volume of filtrate
Q = filtration rate, $dV/d\theta$
K = a constant
A = area of filtering surface
μ = viscosity of filtrate
L = thickness of filter cake
a = a constant
b = a constant
ΔQ_2 = sum of 1st and 2nd order rate corrections
k = 6.6 gal./sq. ft. /hr., blind flow of $Al(OH)_3$ film

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Presented at A.I.Ch.E. Seattle meeting.

* Material has been deposited as document 5757 with the American Documentation Institute, Photoduplication Service, Library of Congress, Washington 25, D.C., and may be obtained for $1.25 for photoprints or $1.25 for 35-mm. microfilm.

CORRECTION

In the article "Radiant Heat Transfer in Sheet Annealing Furnaces," by Bates and Utsumi (page 80, October CEP), all the curves in Figure 1 are countercurrent flow.

preliminary design studies of

Low temperature refrigeration plants-Part 2

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Since ultralow refrigeration must be carried out in a number of steps or stages, there is considerable latitude in choice at each stage. As a result there are a large number of combinations which have been proposed, as indicated by Birmingham *(4)* and Chelton, *et al. (5)*. The choice is influenced by the nature of the refrigerant load. For example, Birmingham *(4)* is concerned with supplying refrigeration solely at the boiling point of hydrogen in order to take care of heat inleakage which results in evaporation. Chelton, *et al.* compare alternative cycles for liquefying hydrogen which call for both refrigeration at the boiling point to remove the latent heat, and refrigeration from ambient down to the boiling point to remove the sensible heat of the gas. For the condition discussed by Birmingham one could supply refrigeration at the constant temperature of boiling hydrogen by means of a single expansion step as by an engine (or turbine) taking saturated hydrogen gas at 5 atm. and expanding it into the wet region at 1 atm. If one chose to avoid the uncertainty of operating an expander into the wet region, helium could be used in a similar Claude cycle. In the case of helium, performance could be improved over that possible with hydrogen by having expansion take place in stages with reheat between stages. Neither of these methods was considered acceptable for the application considered by Birmingham *(4)*, because the specification was given that there be no moving parts for the portable hydrogen tanks connected with the refrigeration systems mounted on the storage vehicle. The solution adopted was the use of a boiling-nitrogen first-stage of refrigeration followed by Joule-Thomson expansion after further cooling by means of a heat exchanger.

These examples serve to show how the useful temperature range differs for the three basic processes:

1. Vapor compression with condensation, throttling, and evaporation
2. Joule-Thomson expansion
3. Expansion through an engine (or turbine).

The first process can be carried out only over a limited-temperature range and requires that heat be removed largely at the upper limit.

The second process can be carried out over a wider temperature range than the first process but has a limit of upper temperature at which it can reject heat.

The third process can be carried out over virtually any temperature range. However, this statement is based solely on an ideal case. In practical refrigeration cycles, heat leakage will occur over a range of temperature so that an intermediate stage of refrigeration may be required to take care of this heat leak. On the other hand, there are instances where a single expansion step is used, even though refrigeration is called for over a wide range of temperature, rather than in a limited range. The single expander is used for simplicity of design.

Distinctions among the three processes can also be found in the characteristics of heat absorption and heat rejection.

Generally, the first process has the major quantity of heat rejection at constant temperature, *d'e*, and the magnitude of this heat rejection is usually several times the equivalent work of compression (depending, of course, on compression ratio). Heat is absorbed, largely at constant temperature, as *fg*, but some may also be absorbed over a temperature range as *gn*.

The second process may be considered intermediate between the first and third in that heat may be rejected to another system somewhere along the path *qkd"*, and heat may be absorbed along the path *mn*. The fraction of path *mn* used for heat absorption depends on the arrangement made for heat rejection along *qkd"*, since some of this heat may be picked up by the low-pressure return stream along *mn*.

The third process may be operated with no supplementary refrigeration, and in the ideal case the return low-

pressure stream may be used to supply refrigeration up to temperature n, corresponding to expander inlet at d.

Comparative efficiency

As discussed in the previous paper, the performance of ultralow-temperature-refrigeration systems is to be considered on the basis of a modified coefficient of performance (neglecting power available from expanders).

(Ideal) *Coefficient of Performance = Heat abstracted from process / Power supplied to Compressors $= T_p/T_o$ (1)

Where T_p = mean temperature of heat removal from process.

$T_p = \Delta Q/\Delta S = \Delta H/\Delta S$ (2)

ΔQ = heat removed from process fluid (cf. Figure 5) = enthalpy change ΔH as shown on Figure 5 for the entire process: $\Delta H = H_A - H_F$

ΔS = entropy change corresponding to heat removal from process fluid (cf. Figure 5) $\Delta S = S_A - S_F$

T_o = mean temperature of heat rejection in compression process assuming multistage compression with intercooling between stages. Compression work = $(E_{co})(T_o)(\Delta S_{co})$ where E_{co} is the adiabatic efficiency of the compressor and ΔS_{co} is the change in entropy corresponding to isothermal compresssion from inlet to discharge pressure at temperature T_o. (3)

The actual coefficient of performance is the modified ideal coefficient of performance, multiplied by a number of

Parts 1 and 2 of this article in the November and December issues represent Part IV of author's work on low temperature refrigeration.

efficiency terms related to the several phases of the refrigeration process:

(Actual coefficient of performance) $= E_{co}\, E_{ex}\, E_{ad}\, E_{hs}\, E_{pr}\, E_{dp}\, E_{in}\, (T_p/T_o)$ (4)

E_{ex} = adiabatic efficiency of each stage of the expander (5)

$E_{ex} = (\Delta H_{adiabatic})/(\Delta H_{isentropic})$

Note: where E_{ex} = zero (isenthalpic expansion) Equation (13) is employed.

E_{ad} = ratio of mean temperature associated with isentropic expansion to mean temperatures associated with actual adiabatic expansion.

$E_{ad} = (T_{dj})/(T_{dj}') = (T_{jn})/(T_j')$ (6)

$T_{jn} = (\Delta H_{jn})/(\Delta S_{jn})$ and

$T_{j'n} = (\Delta H_{j'n})/(\Delta S_{j'n})$

• *Note:* Where the Joule-Thomson coefficient, $(\partial T/\partial P)_H$ not equal 0 the value of E_{ad} is obtained from Equation (12); $E_{ad} = E_{re}/E_{ex}$

E_{hs} = efficiency of refrigerant heat exchanger as related to the net refrigeration available from the expander.

$$E_{hs} = \frac{H_n' - H_j'}{H_d - H_j'} \quad (7)$$

$E_{pr} = T_r/T_p$ = ratio of mean temperature at which refrigeration is available from expansion device to the mean temperature required for cooling process fluid. (8)

$T_r = T_{jn}$ = as defined under Equation (6) and for an ideal gas, T_r is the log mean of temperatures d and j (9)

$T_r = (T_d - T_j)/\ln (T_d/T_j)$ (for ideal gas only)

E_{dp} = efficiency of the cycle as affected by the pressure losses in the piping, heat exchangers, intercoolers, and aftercoolers. The pressure drops are too small to be indicated meaningfully on the T-S or PV diagrams. (10)

$(E_{dp} = 1 - \Sigma(\Delta P/P)/\ln (P_d/P_s)$ where $\Sigma(\Delta P/P)$ represents the summation of all pressure drop ratios in the cycle. A discussion of design for optimum pressure drop ratios is given in the earlier paper (*1*).

E_{in} = Heat abstracted from process / (Heat infiltration + Heat abstracted from process)

The last two efficiency terms apply in general to all refrigeration processes and will not be treated further in this paper. The compressor efficiency term is also common to all systems. Cascade systems or multiple refrigerant fluid systems will have more than one compressor system, but the analysis remains essentially the same as for a single compressor set.

Attention will be paid to the following three design features:

1. Expansion process
2. Performance of the heat exchanger cooling down the refrigerant from c to d (d' or d''), and supplementary refrigeration, if any, along path cde.
3. Value of E_{pr}, which is essentially consideration of how well the refrigerant process matches the requirements for refrigeration of the process fluid.

Expansion process

The efficiency of the expansion process is given by the product of the two efficiency terms, E_{ex} and E_{ad}, which in the case of a refrigerant gas approaching ideal gas properties, is identical with:

$(E_{ex})(E_{ad}) \equiv E_{re} \equiv (\Delta S_{j'n})/(\Delta S_{jn})$ (12)

However, with most real gases used in the Claude cycle, there is a Joule-Thomson effect which cannot be neglected. If only a single expander is used, the low-pressure refrigerant cannot be heated to temperature n (in supplying refrigeration to the process stream). Rather the low-pressure stream must enter the main refrigerant heat exchanger at tempera-

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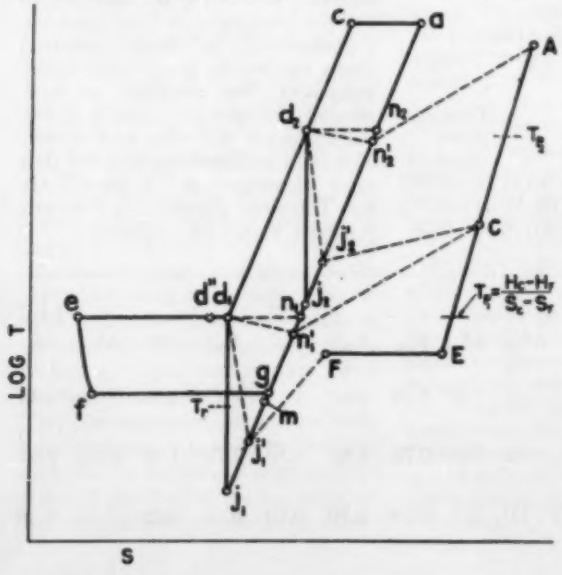

Figure 5. Log temperature vs. entropy — illustration of refrigeration in two stages showing process load and refrigerant.

continued

ture n' having such a value that the enthalpy change from n' to a must be slightly larger than from c to d (d'). Where there is such a Joule-Thomson effect, the condition at the expander inlet will be more closely represented by d' than by d. One can supply the extra enthalpy change in the high-pressure stream by means of an auxiliary refrigeration cycle somewhere along path cd'; thus the low pressure stream is allowed to approach more closely to temperature n (equal to d').

The value of the term E_{re} (expansion process efficiency) is similar for the other processes:

Joule-Thomson (Hampson cycle) $E_{re}=\Delta S_{mn}/\Delta S_d''$ (13)

Throttling of condensate (Rankine cycle) $E_{re}=\Delta S_{fn}/\Delta S_{en}$ (14)

The numerical value of E_{re} necessarily depends on the conditions of the process. With an expander it is primarily a function of the adiabatic efficiency, so that with an efficient expander, E_{re} might exceed 0.80. This compares with a possible value of E_{re} of over 0.90 for the throttling of condensate, and less than 0.67 for Joule-Thomson expansion. However, these efficiency terms are not strictly comparable. The entropy change represents two components — (a) the entropy change corresponding to the compressor work, and (b) the entropy change corresponding to heat rejection to another refrigerant cycle or loop. In the case of the expansion engine, one may operate with the small increment of entropy (associated with a nonideal gas) being supplied by the refrigeration available from the expander. With the Joule-Thomson, one can vary the amount of supplementary refrigeration and the temperature at which it is supplied and thus alter the amount of refrigeration available along path mn'. The vapor-compression cycle with flashing of condensed liquid can be modified by subcooling of the condensate, and thus reduce the amount of refrigeration available along path gn, but increase it along fg, by moving point f to the left. Normally, this is a small effect, but such subcooling is usually practiced in order to avoid flashing of the saturated liquid in piping ahead of the main restriction.

Since heat must be removed from the condensing vapor, the value of E_{re} is in itself not sufficient for comparing this cycle with the others. A comparison can be made in the following fashion. The entropy change can be divided into two components—that of the compressor work and that of the refrigerant work associated with heat rejection from the high-pressure stream.

Let ΔS_{dn} be the entropy change associated with the compressor assuming perfect heat exchange in cooling down the refrigerant from c to d. (15)

Let ΔS_{ed} be the entropy change associated with heat rejection whether the path is represented by dd', dd'' or de. (16)

Each of these entropy change values should be corrected to allow for the inefficiency of the process of transferring heat to the refrigerant stream.

Let $\Delta S_1=\Delta S_{dn}/E_{hc}$ (17)

$\Delta S_2=\Delta S_{ed}/(E_{pr}' E_{re}' E_{hc}')$ (18)

The performance of the refrigerant gas heat exchanger can usually be made fairly good, so that E_{hc} might have, for example, a value of 0.78. For the removal of heat in the condenser, or for the furnishing of supplementary refrigeration in the Joule-Thomson process there are several efficiency terms comparable to those associated with cooling down the process stream, except that in this case the refrigerant stream of the lower temperature refrigerant is treated as the process stream. The prime is added to indicate that reference is made to the higher temperature refrigerant loop. Some reasonable values can be assigned to indicate the comparable performance of the three processes (see below).

The over-all efficiency of the cycles then can be compared as follows:

Cooling-down efficiency

$$= \frac{(\Delta S_{dn} + \Delta S_{ed})(E_{re})}{\Delta S_1 + \Delta S_2}$$

Thus:

		Cooling-down efficiency
Claude	(1.0)	(0.70)/1.28=0.547
Hampson	(1.25)	(0.60)/2.01=0.373
Rankine	(3.5)	(0.90)/9.00=0.35

The cooling-down efficiency may be looked at as the product of the efficiency of the particular expansion process and the heat transfer process by which heat is removed from the refrigerant prior to expansion.

Heat exchanger efficiency

Since the cooling-down efficiency includes the heat-exchanger efficiency, improvement can be sought by improving the effectiveness of the refrigerant gas heat exchanger, represented by exchange between na and dc, or by the equivalent in the stream supplying auxiliary refrigeration. This improvement will result in better performance of all processes. However, as a practical matter, the variation in heat capacity of the high-pressure stream being larger than the variation of the low-pressure stream, there is a limit in improvement which can be exceeded only by introducing auxiliary refrigeration at several places in the process so as to avoid pinches in temperature difference between high- and low-pressure streams. Expressed in another way—high performance is associated with close approach to ideal gas properties of the refrigerant stream.

Process efficiency

Improvement of the Hampson cycle can be looked for by selection of the optimum zones for supplying auxiliary refrigeration. This means designing for minimum temperature difference between streams. Freedom to select the best conditions is afforded by using expanders to supply this auxiliary refrigeration. In the case of hydrogen liquefaction, boiling nitrogen is used to remove heat at the intermediate temperature level. Some flexibility is afforded by arranging to boil the nitrogen at reduced pressure. Unfortunately, in large industrial plants this results in extremely bulky equipment. The possibility of compressing the nitrogen starting at the boiling point was discussed earlier. This is an inefficient method and thus some advantages of the process are lost. Therefore, if possible, a hydrogen expander should be employed.

	ΔS_{dn}	ΔS_{ed}	E_{hc}	E_{pr}'	E_{rc}'	E_{hc}'	ΔS_1	ΔS_2	Total ΔS
1. Claude (expander)	1.0	0.0	0.78				1.28		1.28
2. Hampson (Joule-Thomson)	1.0	0.25	0.78	0.80	0.70	0.78	1.28	0.73	2.01
3. Rankine (vapor compress.)	1.0	2.5	0.78	0.76	0.70	0.78	1.28	7.72	9.00

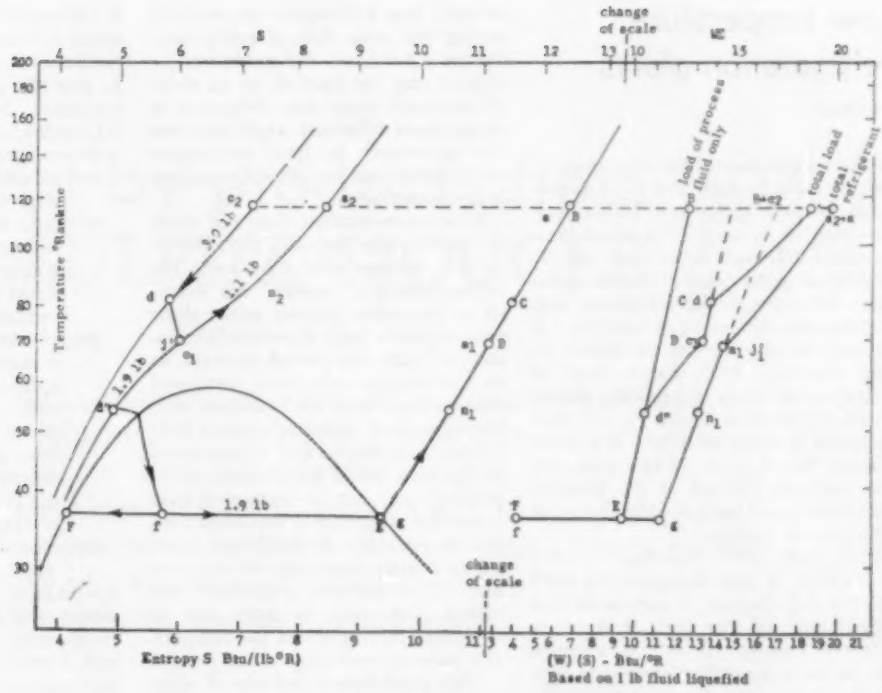

Figure 6. Low temperature vs. (mass flow) (entropy)—illustration of graphical cycle analysis.

The Rankine cycle is often used with other cycles in a way that the two complement each other and a high over-all performance is attained. Thus while the cooling down efficiency of 0.35 might be applicable to a cascade of Rankine cycles, the value of $E_{ro}>0.90$ might obtain where the Rankine cycle, following at a lower temperature level either a Claude- or Hampson-expansion system, permits these two processes to operate in a higher temperature area, where they are likely to be more efficient, and then, in a sense, the Rankine cycle carries the refrigeration to the required operating level without greatly increasing the system power. Thus while a cascade of vapor compression cycles would offer no particular advantage, a single loop of vapor compression, expansion, and evaporation is often desirable.

Generally speaking, the process efficiency of most cycles is likely to be higher for the liquefaction component of the refrigerant load than for the sensible cooling component. This results from some form of composite of cycles in the lower temperature stages including vapor compression with condensation, and either a Joule-Thomson expansion or a Claude-expansion engine supplying the refrigeration for the condensation or cooling-down of the fluid in the last stage of the series of refrigeration loops. However, there has been some traditional reluctance to use a large number of loops for the intermediate temperature levels. Whether or not this practice is economically justified can be indicated by some form of representation of the nature of losses associated with a limited number of intermediate refrigeration loops.

The procedure is to show the processes on a temperature-entropy plot modified by the entropy change represented not as thermal energy per unit mass of fluid per degree, but as thermal energy per degree. In other words, the entropy is multiplied by the relative proportion of refrigerant required for an arbitrary quantity of process fluid being cooled. Thus, as shown in Figure 6, the enthalpy change of the low-temperature stream in a heat exchanger must equal the enthalpy change of the high-temperature stream, which in terms of entropy values shown will be:

$$\Delta Q' = \Delta Q'' \quad (19)$$

$$T'(W'\Delta S) = T''(W''\Delta S'') \quad (20)$$

where the single prime and the double prime refer respectively to the low temperature stream and the higher temperature stream. The lower temperature stream may be termed the *refrigerant* stream and the higher temperature stream the *load* stream. This practice can be followed even if at one part of the cycle the stream is refrigerant and at another part it is the load.

A stepwise method of setting up this form of presentation is shown with the dual-expansion cycle with engine described by Chelton *et al.*, as an illustration and shown here in approximate form as Figure 6.

1. A line is drawn to represent the cooling down and liquefaction of the process stream, such as BCDEF. This line represents the load, subject to additional loads as the analysis proceeds.

** The procedure indicated here is one of many which can be followed. The writer chooses to represent the load as being simply one of heat removal at atmospheric pressure. In the liquefaction of a gas, there is a set difference in entropy which is unaffected by the process followed in liquefaction. One may compress the gas at about ambient temperature, then remove heat from the compressed gas by some refrigeration process, and finally allow the gas or liquid to flash to the final condition of a liquid at atmospheric pressure. If this is the actual process employed, then according to the procedure described here, the compression of the gas and its subsequent cooling would be treated as the refrigeration process by which the process stream is cooled down and liquefied. Any method of presentation is suitable so long as it is consistent in its treatment.*

2. The lowest temperature stage of refrigeration is drawn on the *T-S* diagram plotted on the left side of the drawing, as path $c_1d''fgn_1a_1$. The refrigerant is assumed heated up almost

continued

Low temperature refrigeration plants

continued

to the temperature of the next stage of refrigeration D such that it is shown with the path going to a_1 rather than stopping at n_1 or g. The small temperature difference between a_1 and D, representing the effect of end-temperature difference in the refrigerant and process-stream heat exchangers, is treated as too small to be shown on the diagram. This lowest stage of refrigeration cools the process stream from temperature, T_D to T_B and then liquefies it along path EF. If it is assumed that there is no heat leak, the net enthalpy change of the refrigerant must equal the enthalpy change of the process stream:

$$W'(H_{a1}-H_f')=W''(H_D-H_F) \qquad (21)$$

Path fg is now drawn to the right of the T-S diagram to such scale that the length of this path is equal to $(W'/W'')(\Delta S_{FB})$. If W'' is assumed to be unity mass flow, then path $gn'f'$ is drawn to have a slope, $[d(\ln T)/ds]\,(1/W')$ where $d(\ln T)/dS$ is the slope of the curve for unity mass of the refrigerant.

3. In similar fashion the load curve is now drawn in to represent the sum of the process fluid load and the load imposed by the refrigerant being cooled down from c_1 to d''. This shows up vividly as the change in slope of the load curve ED at point d'' where the refrigerant load is graphically added to the process load.

4. From c_1 to d the slope of the load curve is that for the process fluid only because the refrigerant is being cooled by expansion through the engine, process df'.

5. The intermediate refrigeration required is now calculated and the curves for the total refrigerant-temperature-entropy (WS) and total load are drawn in.

Evaluation of cycle

The curves for load and refrigerant afford a graphical appraisal of the process selected. The efficiency compared with an ideal cycle is given by:

Efficiency = (work of ideal cycle)/(work of actual cycle) (22)

$$\text{Efficiency} = \frac{T_o W_p (S_B - S_F)}{T_o W_r (S_{[a2+a]} - S_f)}$$

The fact that there is a comparatively large vertical distance between the load curve and the refrigerant curve indicates that some improvement in cycle performance is possible by reducing the end temperature differences in heat exchangers and thus reducing the mass flow of refrigerant. On the other hand, the conditions indicated may be justified on an overall economic basis—any reduction in temperature difference would increase the investment in heat exchangers which might not be offset by savings in operating cost.

This representation does not show the entire cycle but only that following the streams after they leave the boiling nitrogen coolers. An analysis of the entire process might show comparatively large irreversibilities associated with the use of nitrogen as an intermediate refrigerant compared with cooling down the hydrogen, with hydrogen itself as the refrigerant fluid in expansion stages. Any improvement of this kind, while thermodynamically justified, may not be warranted from a number of practical considerations, such as the ready availability of liquid nitrogen from plants already in operation. The analysis suggested here makes it possible to carry out an evaluation which shows the comparative losses at each stage of the process.

This procedure is but one of many methods of indicating performance of low-temperature processes. In the previous paper (*1*), a basis is offered for evaluation of processes as a whole or in part. This appraisal ties in with the performance of components, such as expanders, compressors, and heat exchangers.

ACKNOWLEDGMENT

Considerable help from others in this field is gratefully acknowledged. T. Kusuda and R. Kamp of Worthington Corporation discussed many ideas given here and assisted in the preparation of the graphical presentation. L. Schmerzler of Newark College of Engineering offered a number of suggestions. W. E. Gifford of Arthur D. Little, Inc. reviewed the first section and indicated where improvements could be made. Gratitude is also expressed to the Worthington Corporation for affording the time for the organizing of this material.

NOTATION

C.O.P. = coefficient of performance = (heat removed)/(work input)
Ideal C.O.P. (of reversible cycle) = (heat removed)/(net work input)
(Ideal) ° C.O.P. (of reversible cycle) = (heat removed)/(compressor work)
This is a modified C.O.P. in which the work available from low-temperature expanders is neglected.

E = efficiency. Any one of several terms by which the ideal or (ideal) ° coefficient of performance is multiplied to give the actual coefficient of performance. The subscripts applied to E have the following meanings:

co = compressor
ex = adiabatic efficiency of each stage of the expander
ad = ratio of mean temperature associated with isentropic expansion to mean temperature associated with actual adiabatic expansion
he = efficiency of refrigerant heat exchanger as related to net refrigeration available from expander.
pr = ratio of mean temperature at which refrigeration is available from expansion device to mean temperature required for cooling process fluid (or other loop of cycle)
re = expansion process efficiency as given by Eq. (12), (13), (14)

H = enthalpy B.t.u./lb. or units consistent with S

P = absolute pressure. Subscripts *su* and *di* refer respectively to suction of first stage of compressor and pressure at discharge of final aftercooler.

S = entropy. B.t.u./(lb.°R) or units consistent with H and T.

T = temperature. °R. (absolute). With subscript of two letters it generally refers to mean of temperature over interval designated. For a constant pressure process: (and no chemical change)

$$T_{mean} = (\Delta H)/(\Delta S)$$

Subscript r = refrigerant fluid

Subscript p = process fluid or fluid from which heat is being removed.

W = weight rate of flow, lb./hr. or simply weight, lb. or consistent units.

W_p = process fluid — weight flow taken as unity for Equation (22) or Figure 6.

W_r = actual refrigerant flow.

Presented at Baltimore A.I.Ch.E. Meeting

Correction

In the article, "Chromatographic Analyzer for Determining Trace Hydrocarbons in Air Separation Plants," (September, page 49), Table 2 shown below was inadvertently omitted.

Table 2. Comparison of Mass Spectrometer and Chromatographic Analyses

	MS	Chromatograph (parts per million)
Ethane	25.0	24.0
Ethylene	1.0	1.0
Propane	19.4	24.0
Propylene	1.0	....
i-Butane	1.2	1.5
n-Butane	0.7	0.8

Chemical by-products from SPENT SULFITE LIQUORS

The chemical engineering involved in a number of processes to recover chemical by-products from sulfite process liquor. Since about one-half the original wood is dissolved in the liquor, some three million tons, on a dry basis, of the waste material is produced in the U.S. each year. Much is still discharged into the nearest water and represents both an economic waste and a pollution problem.

L. M. Whitmore, Jr. and A. J. Wiley
Sulphite Pulp Manufacturers' Research League, Appleton, Wisconsin

To produce cellulose pulp by the sulfite process, wood chips are heated under pressure in an aqueous bisulfite solution containing an excess of sulfur dioxide. During this digestion the lignin is made soluble by sulfonation and the hemicelluloses are hydrolyzed to pentose and hexose sugars, giving a spent liquor with about ten percent solids. The total quantity of such solids produced annually in the United States is around three million tons, of which only a small percentage is utilized. Most of this liquor is still discarded into some convenient body of water, where the high biological oxygen demand of the sugars has a tendency to disturb the normal balance of aquatic life. The emphasis on utilization rather than disposal of this liquor is increasing, not only because of restrictive legislation, but also because of the potentials for new products and profits. Since wood is a replenishable raw material, it should have an increasing advantage over such raw materials as coal, oil, and natural gas which are not renewable. The cooperative research program of the Sulphite Pulp Manufacturers' Research League is supported by companies which produce 43% of the total sulfite pulp made in the United States.

Spent sulfite liquor has a number of characteristics which make utilization difficult. Calcium bisulfite is generally used in the cooking acid and it is not feasible to recover calcium and sulfur from the spent liquor by evaporation and burning. Concentrated liquor can be burned to recover heat, but the B.t.u. content of the liquor solids is only about half that of coal. One important problem is that many blow pits have been designed and operated primarily to facilitate pulp washing, and this has resulted in large volumes of rather dilute liquor. Improvements in blow-pit operation and the use of countercurrent pulp-washing systems are making it possible not only to collect a higher percentage of the available liquor solids but also to increase the concentration of the liquor. Another difficulty is that much of the equipment coming in contact with the liquor must be constructed of stainless steel to prevent corrosion. Furthermore, with calcium base liquor, there is a tendency for calcium sulfate to form scale in pipes and on heat transfer surfaces, as well as sludge in evaporated liquor. However, several special types of evaporation equipment have been developed since 1940 which will operate satisfactorily.

Unmodified spent sulfite liquor has a number of low-grade uses, such as roadbinder and fuel. However, the most promising approach to profitable utilization seems to be separation of the crude mixture into its various components. The liquor varies considerably with the kind of wood and the cooking conditions. Table 1 gives the approximate composition of the spent liquors from softwood and hardwood.

The basic fractionation of spent sulfite liquor is separation of the sugars and the lignosulfonates. Desugared lignosulfonates, whether obtained by fermentation or precipitation, have some advantage over whole liquor for many uses. Most of the sugars can be removed by various microorganisms. Another method used to separate lignosulfonates and sugars is the Howard process, which consists of a three-stage precipitation of nonsugar solids with lime. Calcium sulfite, which constitutes the first precipitate,

continued

. . . while the sugars in whole liquor can be utilized to produce such chemicals as lactic acid, acetone, and butanol, the only commercially important fermentation products are ethanol and yeast.

continued

is used in preparation of fresh cooking acid. Additional lime precipitates calcium lignosulfonates, and the final inorganic precipitate is returned to the first stage of the process. The effluent contains sugar decomposition products and is not suitable for fermentation.

Most of the whole liquor or desugared liquor products are marketed as relatively crude mixtures for prices ranging from 5 to 10 ¢/lb. Processing of these products is usually limited to base exchange, evaporation, and drying. The majority of large-volume markets for sulfite liquor products are now based on adhesive or surface-active properties. Uses as adhesives include foundry core binders and linoleum cement. Surface activity is associated with the lignosulfonates, which are polyelectrolytes, having both hydrophilic and hydrophobic groups. Products depending on surface activity are dispersants and emulsifiers. Lignosulfonates can also be used to sequester certain cations, to precipitate soluble proteins, as a base exchange material, and as a filler in leather.

Table 1. Composition of Spent Sulfite Liquor

Lignosulfonates	65%
Sugars	20
Ash	10
Miscellaneous	5
	100%

	Hardwood	Softwood
Hexose sugars (mannose, glucose, galactose)	6%	14%
Pentose sugars (xylose, arabinose)	14%	6%

The sugars in whole liquor can be utilized by various microorganisms to produce such chemicals as lactic acid, acetone, and butanol. However, the only commercially important fermentation products are ethyl alcohol and yeast. Since the presence of free sulfur dioxide has an inhibitory effect on yeast, the liquor must either be stripped or neutralized before fermentation.

Ethyl alcohol is now being produced by one mill in this country, two in Canada, and many more in Europe, where alcohol production is subsidized by several governments for automotive fuel and various other uses. An outline of the continuous process is shown in Figure 1. Lime is added to the raw liquor to neutralize excess acidity before fermentation. A by-product of this anaerobic fermentation is carbon dioxide. Yeast is centrifuged from the fermented liquor and recycled. The concentration of alcohol in the fermented wort is only about 1%, compared with 5 to 10% for molasses and grain media, so recovery is more difficult. Also, the type of yeast used to produce alcohol can utilize only hexose sugars, while the Torula yeast produced for feed and food use can metabolize pentoses as well as hexoses. Holding times of around 12 hr. are used and about 42 lb. alcohol can be produced/100 lb. hexose sugars entering the fermentor.

Yeast for human food and animal feed is now being produced by two companies in Wisconsin. Since yeast is about 50% protein and rich in vitamins, its nutritional value is high. It is also a good source of products such as sterols, nucleic acids, and enzymes. Figure 2 shows an outline of the continuous yeast process. The liquor is steam-stripped to remove sulfur dioxide and fed continuously to an open tank with an operating capacity of about 45,000 gal. The liberated sulfur dioxide can be used in making fresh cooking acid. Ammonia, phos-

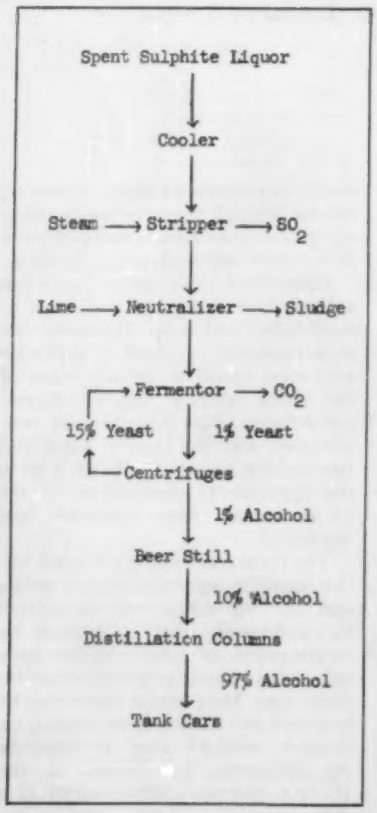

Figure 1. Ethyl alcohol from spent sulfite liquor

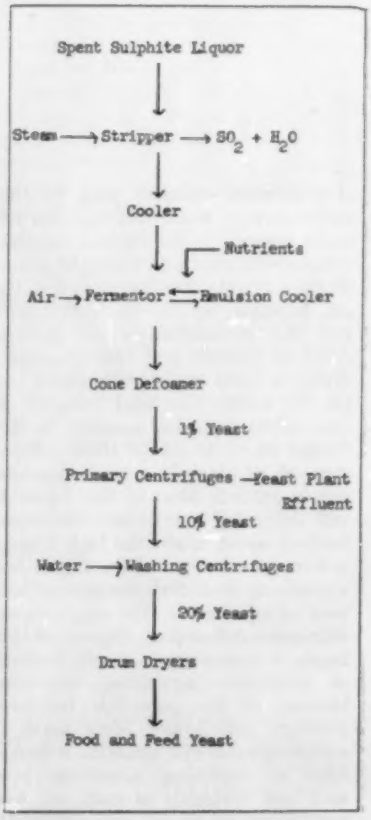

Figure 2. Food yeast from spent sulfite liquor

phorus, and potassium are added as nutrients. A holding time of about 4 hr. results in around 90% removal of the sugars and approximately ½ lb. dry yeast is produced for each pound of total sugar in the feed liquor. The acidity is continuously controlled at about *p*H 5. A constant temperature of around 84° F. is maintained by using a heat exchanger to remove the heat generated during the fermentation, which averages about 7,000 B.t.u./lb. yeast. Because of the vigorous agitation and aeration, wort in the fermentor is in the form of an emulsion containing roughly equal volumes of liquid and gas. Cooling the emulsion is difficult since the heat transfer coefficient is low. Concentration of the liquor before fermentation would increase the fermentor capacity. However, yeast would be more difficult to centrifuge from a liquor with a higher specific gravity, and additional washing of the centrifuged yeast would be needed.

Figure 3 shows a Waldhof-type fermentor with the aeration wheel located at the bottom of a central draft tube. An air-supply pipe goes to the aeration wheel through the center of the draft tube, and air is forced through horizontal tubes and released at the periphery of the rotating wheel. The aerator also acts as a liquor recirculation pump, sending the liquid from the bottom of the draft tube toward the sides of the fermentor, and creating the circulation pattern shown in the figure. This type of aeration helps to control the foaming tendency of spent sulfite liquor by a centrifugal effect.

A process for separation of sugars from the liquor involving a reactive solvent extraction is being developed by the League, and this process is outlined in Figure 4. The whole liquor is spray dried and then refluxed with acetone containing a catalytic amount of concentrated sulfuric acid. The sugars form diacetone derivatives which are soluble in acetone and can be filtered or centrifuged from the acetone-insoluble residue. In addition to reaction rates, diffusion rates of both reactants and products through the insoluble material must be considered. A small percentage of water in the reaction mixture will increase diffusion rates and lower solvent recovery costs, but at the same time it will tend to hydrolyze the sugar derivatives and make the insoluble material gummy and difficult to separate. As temperature, reaction time, and acid concentration increase, the recovery of sugars also increases but a

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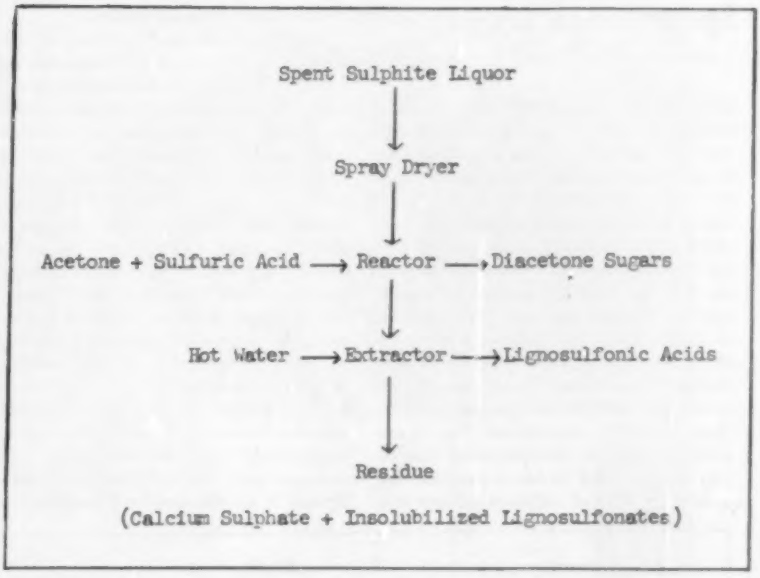

Figure 4. Reactive solvent extraction of spent sulfite liquor solids

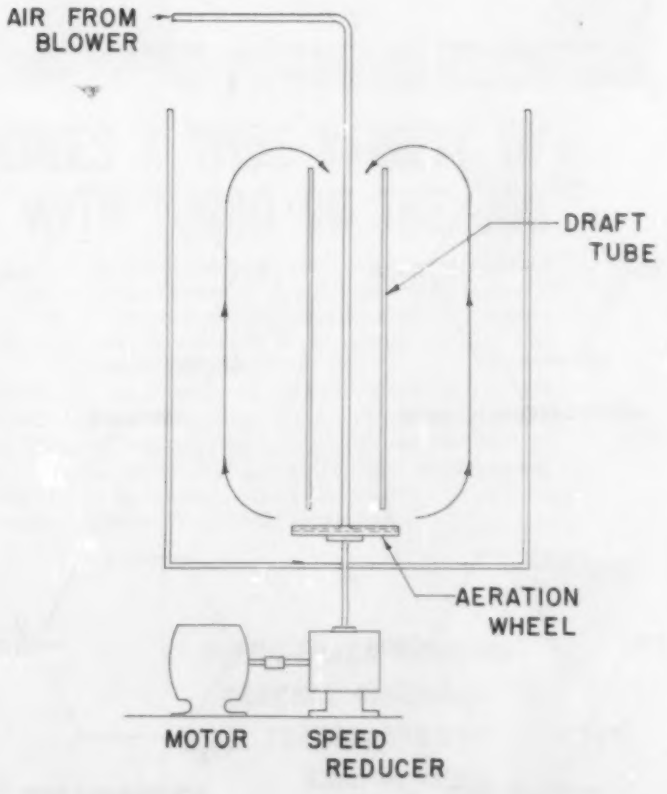

Figure 3. Modified Waldhof fermentor

Spent sulfite liquors

continued

larger percentage of the lignosulfonate residue becomes insoluble in water and less reactive. A fairly wide range of operating conditions is possible and in any commercial process there would be a balance between operating costs, sugar recovery, and lignosulfonate insolubilization. Individual sugars as well as their diacetone or monoacetone derivatives can be obtained in high purity by taking advantage of differences in their properties. Diacetone mannose, for example, is much less soluble in aqueous solution than the other derivatives. The lignosulfonic acids in the extracted residue can be dissolved in hot water, leaving a final residue of calcium sulfate and insolubilized lignosulfonates.

The lignosulfonate portion of the liquor is a mixture of polymers having different degrees of sulfonation and a molecular weight range of about 1000 to 20,000. The structure of lignosulfonic acid is unknown, but there is good evidence that phenylpropane units are building blocks. Figure 5 shows the two principal types of phenylpropane units. There is about one atom of sulfur for each two units. Hardwood contains both the guaiacyl and syringyl varieties, while softwood contains only the guaiacyl type and is therefore used for making vanillin. A few of the other compounds formed by degradation of the guaiacyl variety are also shown in Figure 5. Analogous compounds are formed from the syringyl unit. The ethyl ester of vanillic acid is an efficient food preservative and fungicide. Protocatechuic acid can be used to prepare synthetic fibers of the polyester type.

Vanillin is produced by alkaline oxidation of softwood lignosulfonates at elevated temperatures and pressures. Since the presence of sugars increases the amount of reagents required, the preferred starting materials are either fermented liquor or calcium lignosulfonates which have been precipitated from whole liquor by adding lime. Inorganic oxides and salts such as copper oxide which are easily reduced in alkaline solution are used as catalysts and can be recycled. Temperatures range from 300 to 400°F. and reaction times of 1 to 4 hr. have been used. The *p*H is held above 12 with either lime or sodium hydroxide. Air is added to supply oxygen. In commercial practice that combination of conditions is chosen which results in the lowest cost of production. Yields under these conditions are in the neighborhood of 5 to 10%, based on lignin, although it is possible to obtain yields as high as 30%. Higher temperatures, more oxygen, and more alkali generally increase vanillin yields up to a certain point, beyond which more drastic conditions reduce yields by degradation of the vanillin. Solvent extraction, ion exchange, and formation of the vanillin-bisulfite addition compound are among the techniques used to recover vanillin from the reaction mixture. Two companies in the United States and two in Canada are now producing vanillin from spent sulfite liquor, although one company could supply the entire demand of less than 2,000,000 lb./yr.

There are numerous complex problems associated with these processes which present a real challenge to the ingenuity and resourcefulness of chemical engineers. Even small improvements may become significant because of the large quantities of material involved.

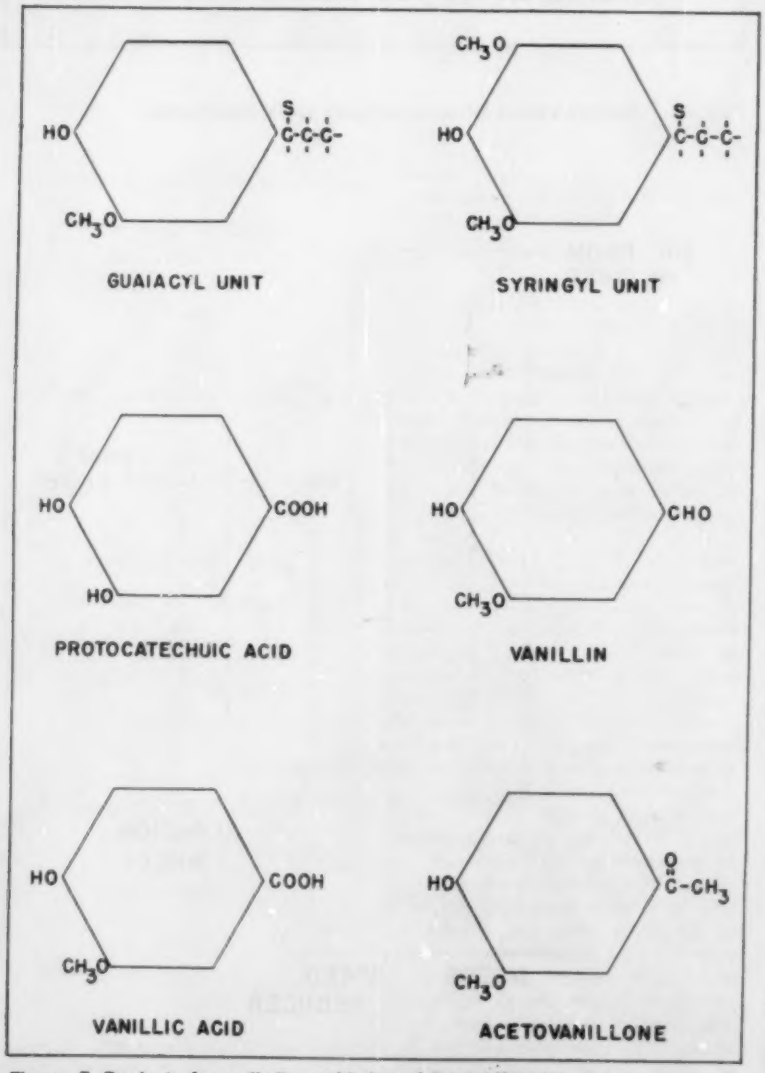

Figure 5. Products from alkaline oxidation of lignosulfonates

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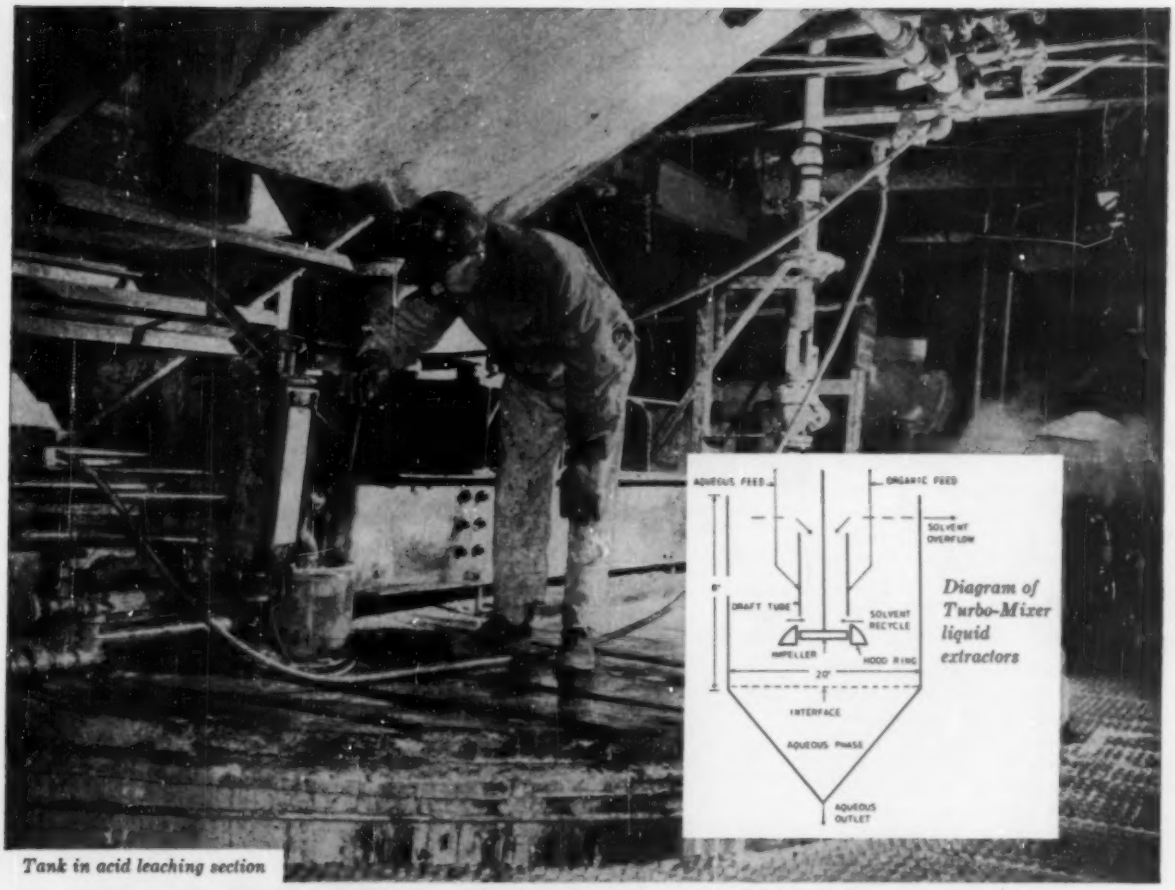

Diagram of Turbo-Mixer liquid extractors

Tank in acid leaching section

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Plasma arc goes commercial

New high-temperature chemical processing applications seen for Linde (Carbide)-developed coating and fabricating method

Equipment components and coatings that will withstand temperatures above 5,000°F. are now available to the designer of chemical processing equipment. Key to the new method is the Linde Plasma Arc Torch which harnesses continuously temperatures up to 30,000°F., said to be the highest controlled temperatures ever used in industry. The device itself, less than two inches in diameter, can melt the most refractory materials known to man without being itself consumed by the intense heat generated.

How it works

The melted particles of the material to be used as coating, or to be built into shapes, are carried through the torch by a stream of inert gas which travels at speeds up to 10,000 miles per hour; temperatures in the center of the plasma have been measured spectroscopically at up to 100,000°F.

How is the nozzle material of an arc plasma torch able to withstand the temperatures generated? The answer is that it doesn't. In a properly designed torch, the arc column does not touch the nozzle. The nozzle wall is cold relative to the arc. Surrounding the arc column proper and adjacent to the nozzle wall is an annular layer of cooler gas having a steep temperature gradient. The relatively cool non-conductive gas at the wall forms a tube of electrical and thermal insulation to stabilize the arc column centrally in the nozzle. Any gas or mixture of gases which does not attack the tungsten cathode can be used in the torch. These include the rare gases, argon and helium, plus nitrogen and hydrogen. The diatomic gases, particularly hydrogen, have good heat transfer characteristics, but are often unacceptable metallurgically.

What it can do

According to Linde, most inorganic materials that melt without decomposing can be used in the plasma arc powder torch. These include:

Refractory metals such as tungsten, tantalum, molybdenum, niobium, and rhenium;

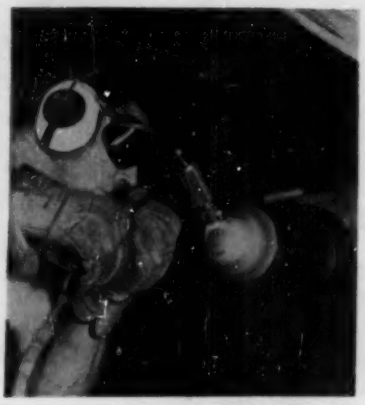
Refractory metal compounds such as the borides of zirconium, tungsten, niobium, tantalum, titanium, and chromium;

Refractory carbides of niobium, hafnium, tantalum, zirconium, titanium, tungsten, and vanadium;

Refractory oxides of thorium, hafnium, magnesium, zirconium, cerium, aluminum;

Noble metals—platinum, palladium, etc., and their alloys.

Coatings made with the plasma arc powder torch are said to have excellent bond to almost any base material, even including some reinforced plastics, graphites, and carbons. The bonds are generally both chemical and mechanical in character, and are claimed superior to those obtained by electroplating, vapor deposit, or metal sprays.



Nose cone for a guided missile is given a heat-resistant tungsten coating with new Linde Plasma Arc Torch.

How shaped parts are made

A mandrel is first prepared to the precise internal diameter of the part to be made. The mandrel is chucked in a lathe, and the material is applied by a back-and-forth movement of the torch over the rotating mandrel. When the proper thickness has been reached, the mandrel is leached out. Brass is often used and then dissolved in nitric acid. There are said to be no known limitations on size or complexity of shape. Accuracy on the order of plus or minus two thousandths of an inch can be maintained.

The chemical processing field is just starting to be investigated, says H. V. Mosby, Linde sales manager (Flame-plating Dept). However, he feels that an important contribution can be made immediately in the field of protective coatings and preparation of catalysts. "Encouraging" results have been obtained in the coating of Inconel screens with manganese oxides for the catalytic decomposition of hydrogen peroxide. Other chemical processing applications which seem immediate are, of course, spray nozzles, valve seats, and linings for high-temperature reaction vessels. Preliminary work has also been done on the use of the plasma arc torch for initiating new chemical reactions.

Boron fuel plant

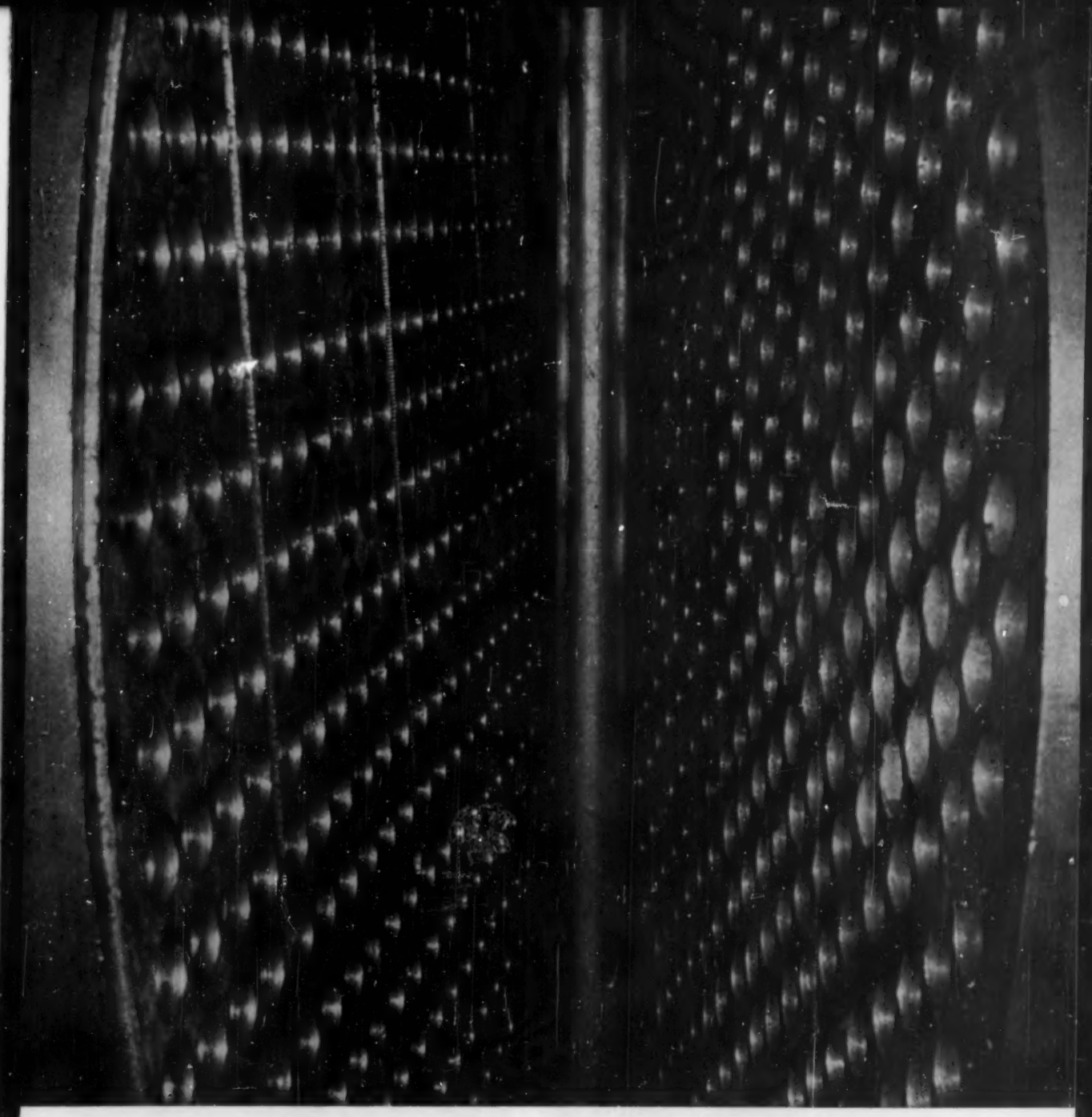
Callery Chemical's large-scale high energy fuel plant was dedicated recently at Muskogee, Oklahoma. Callery built and will operate the $38,000,000 plant for the Navy.

Basically, the plant is composed of four processing units. Although it resembles a refinery in many ways, the unusual technical requirements for producing high-energy fuel are said to make it unique in its operating aspects. The steam plant is nearly 25 times larger than the steam plant in a petroleum refinery of comparable size. This additional thermal capacity is used to bring about reactions which create compounds with higher chemical energy.

Boron is shipped to the plant as boric acid which is then further processed to produce diborane, the basic building block for boron-based fuels. This is one of the steps where large amounts of thermal energy are required. In further processing the boron hydride is combined with carbon and hydrogen to produce HiCal.

One of the chemical engineering developments in the processing is a liquid distillation column which is handling both solids and liquids.

Among the larger units in the plant is a $3,500,000 gas plant which produces hydrogen, CO_2, and nitrogen.



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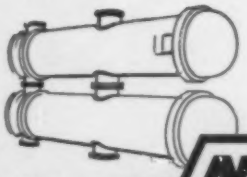

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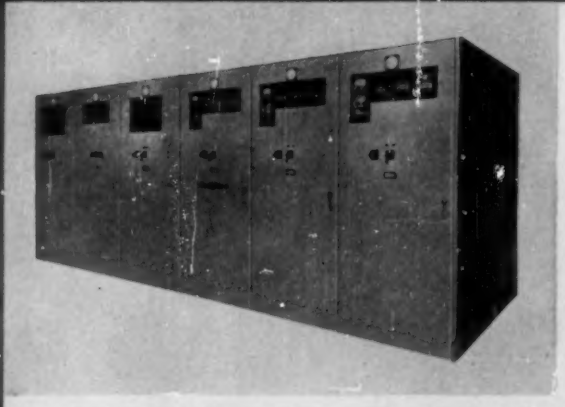

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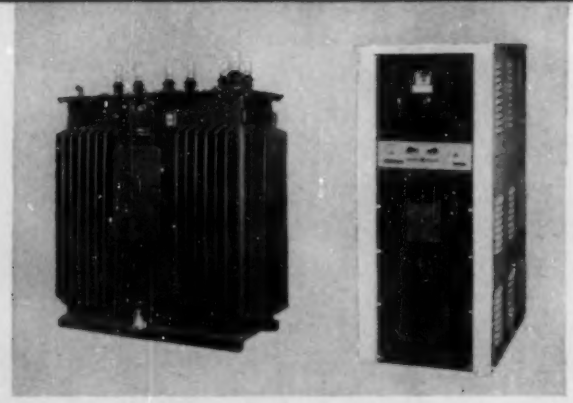

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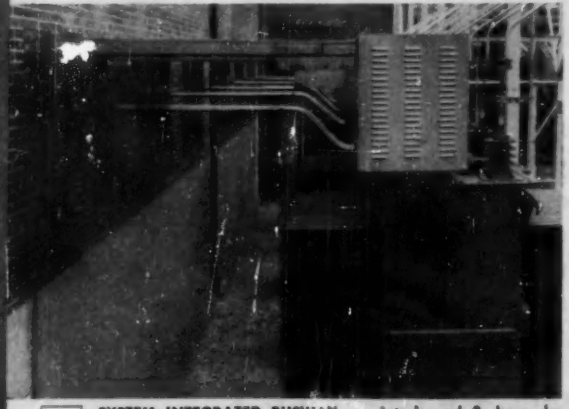

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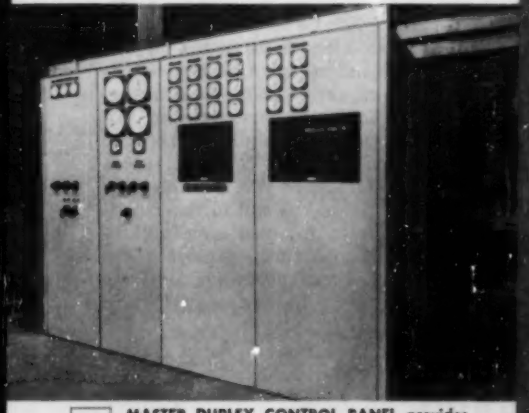

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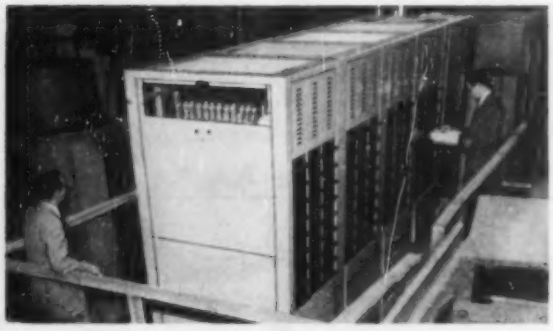

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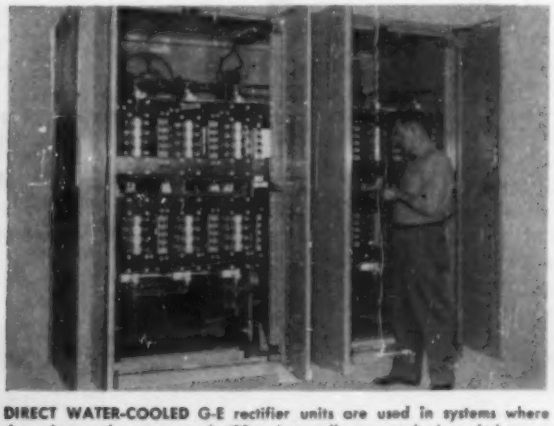
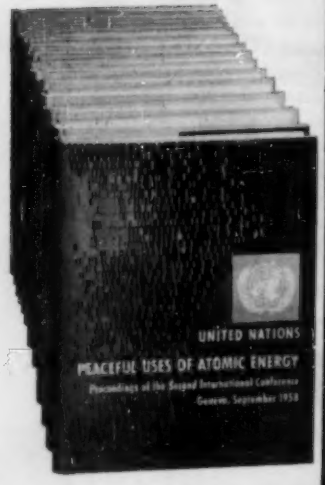


DIRECT WATER-COOLED G-E rectifier units are used in systems where d-c voltages do not exceed 400-v. Internally mounted air-cooled transformers (above) are sometimes used in smaller systems.



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New Research Center dedicated by Grace

All research activities of W. R. Grace have been consolidated in a $5 million facility at Clarksville, Md. Stress will be on new polymers, inorganics, agricultural chemicals

Number one on the research priority list at Grace's just-activated Research Center in Clarksville, Md., will be the search for new polymer materials, say Grace research heads at Clarksville. Polyethylene, polypropylene, other poly-olefins are on the agenda for intensive development work. Company officials refused to comment, however, when asked whether copolymerization of ethylene and propylene was being investigated. (Montecatini of Italy recently exhibited such co-polymers at the National Plastics Exposition in Chicago, several U.S. chemical companies are known to be driving hard in this direction).

Complementing and backing up Grace's polymer program, is an excellently equipped catalyst laboratory, complete with automatic high-pressure continuous units for testing cracking catalysts. In a separate building is a "knockability" rating machine which measures the quality of gasoline samples produced in the catalyst evaluation units.

New insecticide

Displayed at the recent dedication of Grace's Clarksville labs was a new insecticide which kills bugs physically by drying them out. The material, a treated silica aerogel, is a very fine white powder derived from sodium silicate and sulfuric acid. It acts by attacking the essential waxy coating which protects the body moisture of insects. Since its action is thus fundamentally physical, entomologists believe that insects may not be able to develop the resistance noted in the case of some organic insecticides. No harmful effects on animals have been noted; since the material has an amorphous, non-crystalline structure, it is claimed that it could not cause silicosis. Grace, however, emphasizes that the product is still in the experimental stage, and that none will be marketed until further research has been completed and proper authority obtained from the competent Federal agencies.

Shown also was a "floating zone" refiner for the purification of metals and other inorganic materials.

LESS BOILER MAINTENANCE BECAUSE A LJUNGSTROM® CUTS SLAGGING

A Ljungstrom air preheater reduces slagging and cuts boiler downtime by boosting combustion air temperature, in some cases by as much as 1000°F. Whatever fuel you use, hotter combustion air makes it burn more cleanly and completely, with less slag and deposits.

More complete combustion also makes standard equipment work at top efficiency, producing more heat from less fuel. One east coast refinery saves $129,000 a year on their fuel bill through increased furnace efficiency. This increased efficiency contributes to an upgrading of the product by 1½ octane numbers, providing an additional annual profit of $58,000.

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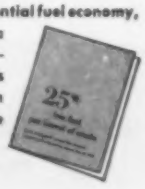
Savings like these — where equipment makes a better product . . . lasts longer . . . and costs less to maintain — can pay for a Ljungstrom air preheater *in as little as two years.* Or, if you use the higher combustion efficiency of a Ljungstrom-equipped furnace to increase throughput, write-off time can be cut to nine months!

For further information on potential fuel economy, write today for your copy of a factual article by O. F. Campbell describing one company's fuel savings with a Ljungstrom air preheater. Call or write The Air Preheater Corporation.



THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.

Application of Nomography to industrial chemical plant control

B. C. Doumas
National Lead Company of Ohio
Cincinnati, Ohio

It is desirable that calculations for chemical production plant control be kept as simple as possible to permit their computation by operating personnel with limited technical training and to minimize possibility for error. Nomography, a tool frequently used by design engineers for repetitive solution of complex problems, provides an excellent means of achieving these ends. This article reports the application of a nomograph for production plant control of the precipitation step of the uranyl ammonium phosphate process. This process is used for recovering uranium from scrap materials at the Fernald plant. Prior to precipitating uranium from clarified hydrochloric acid leach liquors, 75% phosphoric acid is added to such an extent that the ratio of phosphate/uranium is 0.6/1.0 (*1*). This requirement may be expressed mathematically by the following equation:

$$V = 0.000522CB \quad (1)$$

where:

V = volume of 75% H_3PO_4 required, gal.
C = uranium concentration of clarified leach liquor, g./liter
B = volume of leach liquor being precipitated, gal.

By conventional methods (*2*), the nomograph shown in the accompanying Figure 1 was constructed for solution of this equation. With this nomograph and a straightedge, chemical plant operators are able to determine simply, quickly, and accurately phosphoric acid requirements in response to variations in volume and concentration of leach liquors.

As a typical example, for 5500 gal. clarified hydrochloric acid leach liquor containing 15 g./liter uranium, the dashed line on the nomograph indicates that 43 gal. of 75% H_3PO_4 are required.

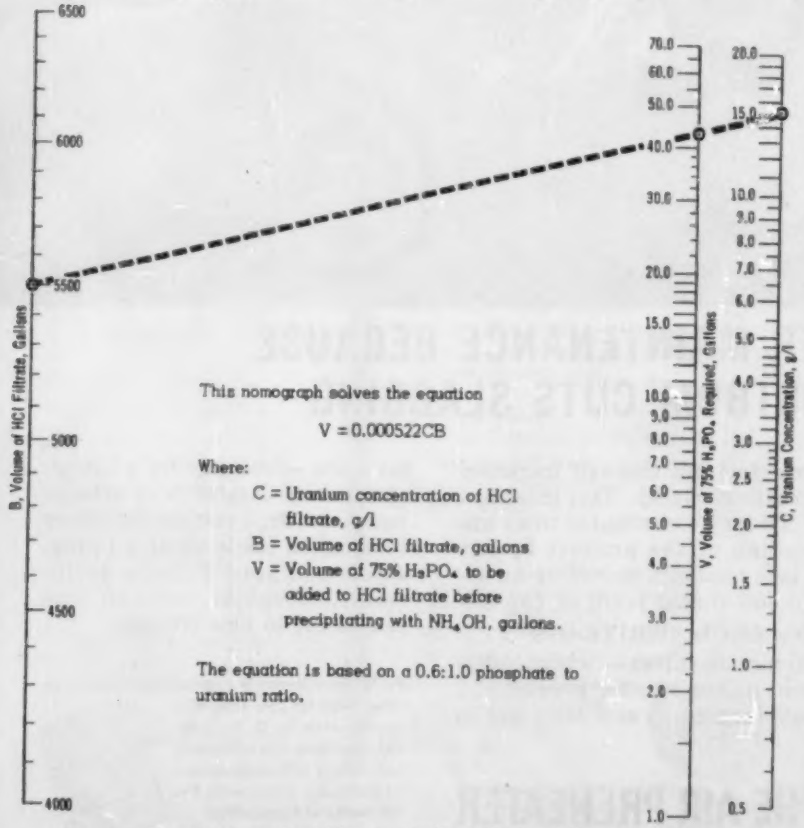

B, Volume of HCl Filtrate, Gallons
V, Volume of 75% H3PO4 Required, Gallons
C, Uranium Concentration, g/l
This nomograph solves the equation
V = 0.000522CB
Where:
C = Uranium concentration of HCl filtrate, g/l
B = Volume of HCl filtrate, gallons
V = Volume of 75% H3PO4 to be added to HCl filtrate before precipitating with NH4OH, gallons.
The equation is based on a 0.6:1.0 phosphate to uranium ratio.

Fig. 1. Phosphoric acid addition to clarified HCl leach liquors of uranium.

LITERATURE CITED

1. Johnson, E. R., E. O. Rutenkroger, A. B. Kreuzmann, and B. C. Doumas, *Chem. Eng. Prog., 53*, 56-F (February, 1957).
2. Davis, D. S., "Empirical Equations and Nomography," Chap. V, McGraw-Hill Book Company, New York (1943).

Nuclear standards called urgent

Advent of privately-owned economic nuclear power plants in U. S. seen imminent — national and international standards to be object of urgent program

Popular belief to the contrary, economic nuclear power (in the range of 8-10 mills) is likely to be a reality in the United States within five or six years, says S. I. Winde, A.I.Ch.E. alternate representative on the Nuclear Standards Board of the American Standards Association. In support of this view, Winde cites recent pronouncements by General Electric predicting 100,000 to 325,000 KW plants producing 8% mill power by 1965, and 450,000 KW plants turning out 6% mill power by 1970.

It was only in 1956, that the American Standards Association took its first plunge into the nuclear field. In September of that year, it formed its Nuclear Standards Board, which, in turn, set up six sectional committees to subdivide the areas of interest:

N2-General and Administrative
N3-Nuclear Instruments
N4-Electric Apparatus and Systems for the Nuclear Field.
N5-Chemical Engineering in the Nuclear Field
N6-Reactor Hazards.
N7-Radiation Protection.

R. P. Genereaux was appointed A.I.Ch.E. representative on the Nuclear Standards Board. A.I.Ch.E. agreed to sponsor the N5 Committee on Chemical Engineering in the Nuclear Field. Chairman of the committee was S.I. Winde and W.W. Kraft was vice-chairman. As of January, 1959, Kraft assumes the chairmanship

continued on page 90

Applying Cryogenics to solve your process problems

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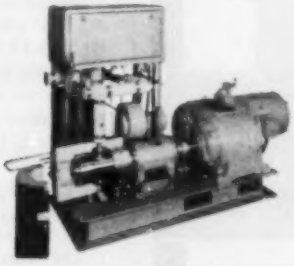
Process research begins with the collection and analysis of fundamental information about the behavior of materials in all types of environments.

At Air Products, process research is not limited to cryogenic systems and processes. The effective use of low temperature processes depends upon their proper integration with all prior and subsequent steps.

Each processing problem is accepted as a new challenge. It is not unexpected for identical feed gases to be processed in entirely different ways to meet diverse objectives. Pilot-type experimental systems are frequently used in this work as an intermediate evaluation tool.



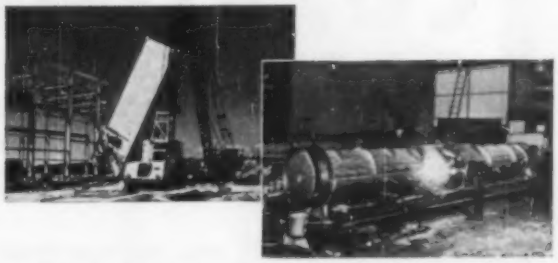
EQUIPMENT DEVELOPMENT

Here is shown a new pumping system currently in production for pumping large quantities of liquid oxygen at 6000 to 12000 psi.

Air Products is constantly developing new types of equipment and improving existing designs to meet new problems.

PROCESS DESIGN

Working from a broad base of fundamental and applied data and from operating experience, Air Products' process designers are accustomed to optimizing cost factors in processes which are dependable, controllable and reliable. This creative phase of the technical function utilizes knowledge gained in all areas of cryogenic experience.



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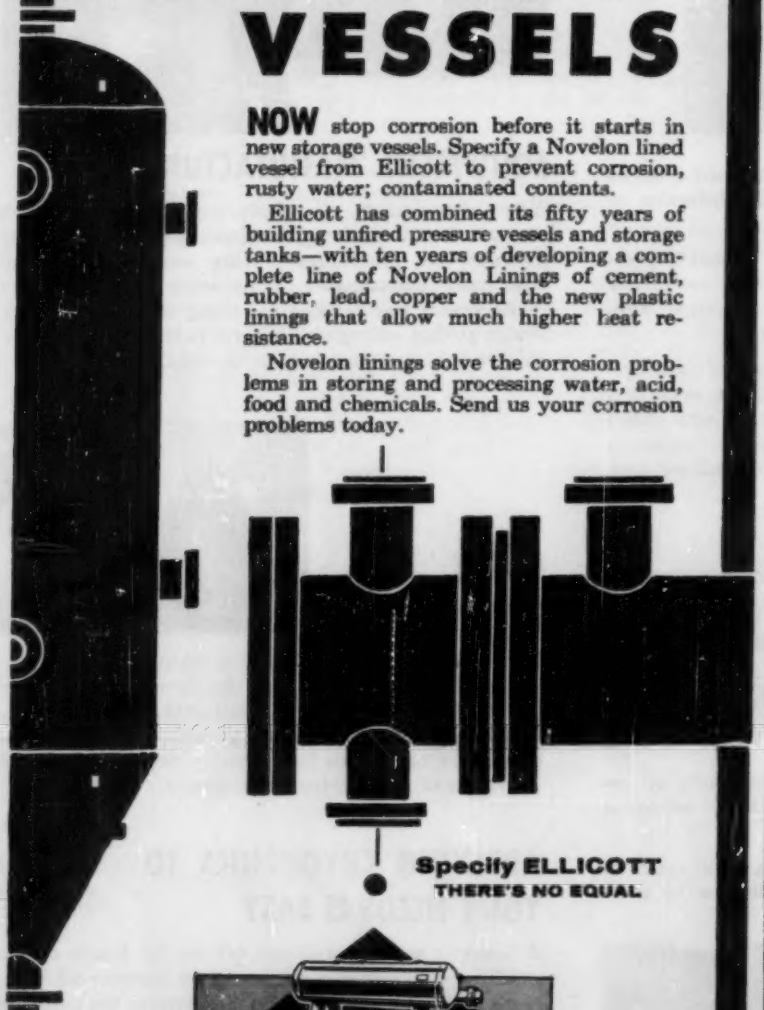

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Nuclear standards

from page 88

and S. Lawroski becomes vice-chairman. All A.I.Ch.E. activity in this field has been under the guidance of the Nuclear Division, formed in 1953.

Two N5 subcommittees are presently of particular interest. Subcommittee N5.4, under the chairmanship of A. C. Jealous, is charged with development of standards for "Use and Handling of Radioisotopes and High Energy Radiation." Also, this subcommittee has accepted the task of acting for the United States in connection with the work of Subcommittee 4 (Isotopes) of Technical Committee 85 of the International Standards Organization (ISO).

Under the chairmanship of M. M. Braidech, subcommittee N5.5 is to develop standards in the field of "Packaging and Transportation of Radioactive Materials." In these two subcommittees, in particular, the widest representation is desirable, and any individual member of A.I.Ch.E. who feels that he can contribute to the work will be welcomed. A.I.Ch.E. is also represented now on two other main sectional committees of ASA's Nuclear Standards Board: on N3 (Instrumentation) by C. G. Lenk; and on N6 (Reactor Safety) by A. D. Duff. A.I.Ch.E. plans to have men on other sectional committees soon. Inquiries on any phase of the N5 program should be directed to Wheaton W. Kraft, Lummus Co., 385 Madison Ave., New York, N. Y.; and on the other sectional committees to Stanley I. Winde, Engineering Dept., Du Pont, Wilmington, Del.

The aim of this work, sums up Genereaux, is "not to establish rigid standards, but to develop guides, codes, and specifications which will be helpful not only to fabricators and operating companies, but to the general public as well." In addition, he adds, this is one more opportunity to work in close liaison with the 30 technical societies and organizations which cooperate with the American Standards Association, and, on a wider scale, with the International Standards Organization.

Shelby, North Carolina, has been selected by Fiber Industries Inc., as the site of its soon-to-be-erected Teron polyester fiber plant. Fiber Industries is a new company jointly owned by Celanese Corp. of America and Imperial Chemical Industries, of Great Britain. (CEP, October, 1958, Scope, p. 29).

New way to pump "dangerous" liquids safely

Goulds vertical process pump Fig. 3181 for handling highly volatile, inflammable, toxic, explosive or other dangerous liquids.

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It's Goulds Fig. 3181 tripod-mounted vertical centrifugal process pump—a new pump specially designed to handle two of your toughest jobs:

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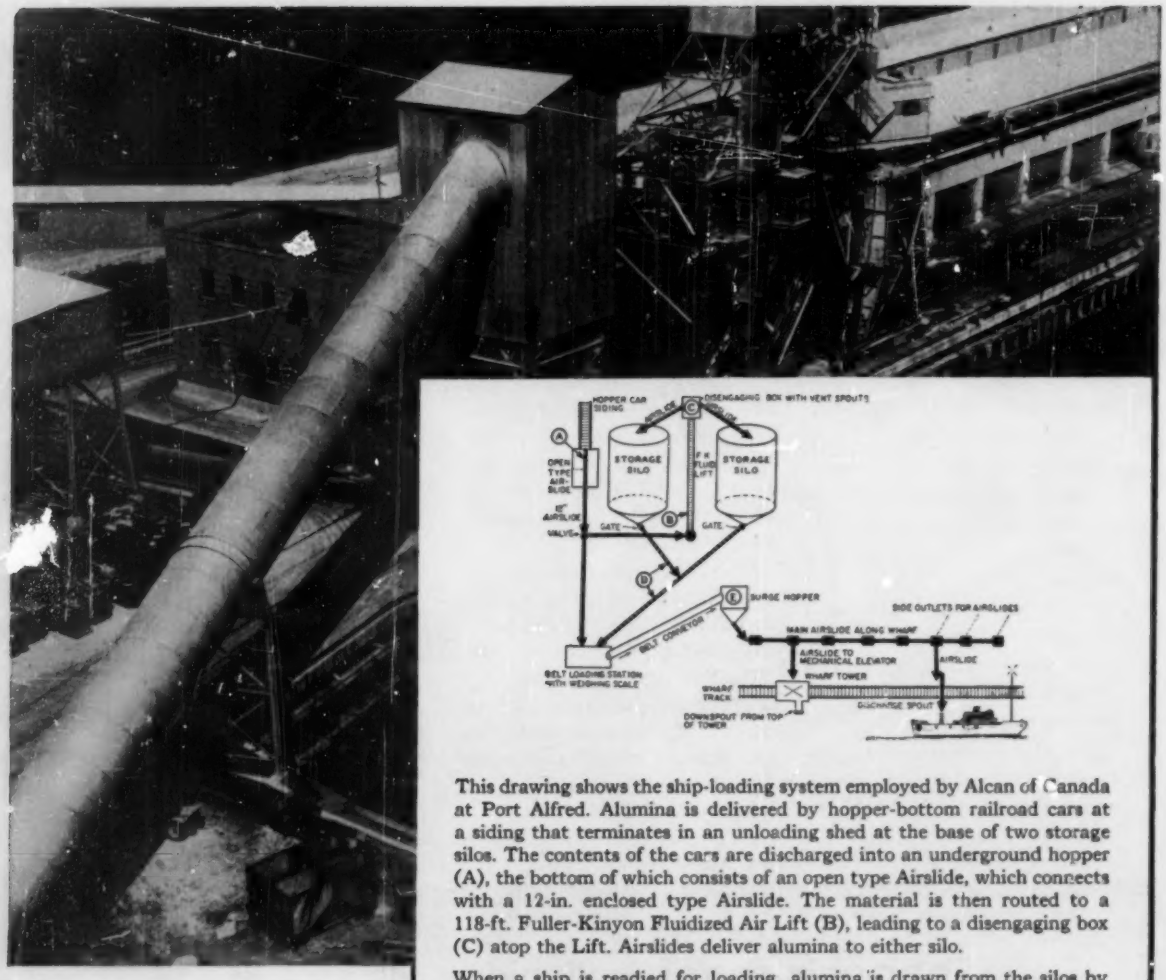

This drawing shows the ship-loading system employed by Alcan of Canada at Port Alfred. Alumina is delivered by hopper-bottom railroad cars at a siding that terminates in an unloading shed at the base of two storage silos. The contents of the cars are discharged into an underground hopper (A), the bottom of which consists of an open type Airslide, which connects with a 12-in. enclosed type Airslide. The material is then routed to a 118-ft. Fuller-Kinyon Fluidized Air Lift (B), leading to a disengaging box (C) atop the Lift. Airslides deliver alumina to either silo.

When a ship is readied for loading, alumina is drawn from the silos by open type Airslides and transported by means of 16-inch Airslides (D) to a belt, which delivers to a surge hopper (E) feeding the 400-ft. long Airslide for conveying to the ship. Air for the operation of the Fuller-Kinyon Fluid Lift is supplied by a Fuller Rotary Compressor.

Here's how ALCAN reduces ship loading time 50%

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Additional equipment consists of two 35-ft. portable F-H Airslides® operating in tandem off of a main 19-in. Airslide running a distance of 400 feet along the roof of the wharf.

These Airslides discharge the alumina directly into the hold of the ship, eliminating the time-consuming shutdown during relocation of the bucket elevator and tower for delivery to various holds.

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Absorption & Oxidation Equipment. Bulletin from Turbo-Mixer Division, General American Transportation Corp. **Circle 81A-D.**

Analyzer, colorimetric. Data from W. A. Taylor on the "Comparator" for pH, chlorine, phosphate, nitrate. Also Handbook, "Modern pH and Chlorine Control." **Circle 136L.**

Anodes, carbon. Custom-built to individual cell requirements. Technical data from Great Lakes Carbon Corp. **Circle 16A.**

Burst Discs, graphite. Burst pressure rating from 1 to 100 lb./sq. in., operating temperatures to 650°F. Technical data and prices from Kearney Industries, Delanium Graphite Div. **Circle 110BL.**

Centrifugals. Tables, design and operating data in Brochure RC-356 from Heyl & Patterson, Inc. **Circle 31A-A.**

Circulators, gas, centrifugal. Data from Foram Corp. (representing Gutehoffnungshuette, West Germany). **Circle 126B.**

Coils, heating. Complete data and prices on the Thermo-Panel Coil from Dean Products, Inc. **Circle 153BR.**

Columns, extraction. Bulletin from Turbo-Mixer Div., General American

continued on page 96

MATERIALS

Additives, paint. Booklet "Chemicals for Resin Emulsions" from Union Carbide Chemicals Co. contains data on thickeners, plasticizers, dispersants, stabilizers. **Circle 17A-A.**

Cloth, wire. New, 94-page catalog and stock list from Cambridge Wire Cloth Co. includes complete metallurgical data. **Circle 142L.**

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continued on page 96

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Fabrication, process equipment. Bulletins from Downingtown Iron Works, Inc. describe facilities and products. **Circle 34A.**

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Condenser, tower-type. Technical data from Croll-Reynolds Co. on the "Convactor." **Circle 22A.**

Controllers, electronic. Bulletin 20-10 from Foxboro Co. describes the "Dynalog" controller. Full-scale spans as narrow as 5°F. **Circle 125A.**

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Cyclones, wet. Complete data in Brochure 1157 from Heyl & Patterson, Inc. **Circle 31A-B.**

Deionizers, single-tank, mixed-bed. Bulletin 512 from Elgin Softener Corp. also describes water softeners, dealkalizers, deaerating heaters, filters. **Circle 122L.**

Dryers, Bulletins 301 and 351 from Bethlehem Foundry & Machine Co. describe batch, continuous, pan types. **Circle 7A.**

Dryers, drum-type. Catalog 384 from Buflovak Equipment Div., Blaw-Knox, describes five different types of drum dryers. **Circle 27A.**

Dryers, pilot-plant. Details from C. G. Sargent's Sons Corp. **Circle 104L.**

Ejectors, steam-jet. Technical data from Heliflow Corp. on Graham jet ejectors. **Circle 30L.**

Equipment, processing. Bulletin 118 from C. O. Bartlett & Snow Co. gives technical details of dryers, coolers, calciners, kilns. **Circle IFC.**

Equipment, processing. Bulletin 968 from Pfaudler Co. contains complete technical data on glassed-steel processing equipment. **Circle 147A-B.**

Equipment, processing. Technical data from Sprout-Waldron. **Circle 24A.**

Equipment, processing, corrosion-resistant. Data from Duriron Co. on valves, pumps, filtration equipment. **Circle 109A.**

Equipment, processing, impervious graphite. Data from National Carbon Co. on "Karbate" heat exchangers, condensers, etc. **Circle 121A.**

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Filters, rotary-drum, molded-plastic. Available with filtering areas from 9 to 100 sq ft. Technical data from Dorr-Oliver, Inc. **Circle 97A.**

Filters, rotary-vacuum. Bulletin KS1-2 from Komline-Sanderson Engineering Corp. **Circle 134L.**

Filter Presses. Catalog from D. R. Sperry contains erection, operating, design, and construction data, specifications. **Circle 130L.**

Flaker, internally-jacketed. Detailed technical information from Goslin-Birmingham Mfg. Co. **Circle 135R.**

Formulating Systems, continuous. Sustained accuracy at rates to 5 tons/hr. Data from Thayer Scale Corp. **Circle 14L.**

Furnaces, industrial. Data from Petro-Chem Development Co. on design and operating features of Isoflow furnaces. **Circle 131A.**

Heat Exchangers. Assembly-line techniques speed fabrication while adhering to highest design standards. Data from M. W. Kellogg Co. **Circle 83A.**

Heat Exchangers. In carbon, alloy, and stainless steels, nickel, aluminum, special low-temperature materials. General Bulletin from Engineers and Fabricators, Inc. **Circle 101A.**

Heat Exchangers. Optimum results guaranteed by computer design system. Details from Yuba Consolidated Industries, Inc. **Circle 119A.**

Heat Exchangers. The "Aero" heat exchanger is almost independent of water supply. Details in Bulletin 132 from Niagara Blower Co. **Circle 136BR.**

Heat Exchangers, extended-surface. Data from Aerofin Corp. **Circle 114L.**

Heat Exchangers, impervious graphite. Improved cubical models available in capacities of 11, 21, 50, 90 sq. ft. of transfer surface. Details from Falls Industries, Inc. **Circle 10L.**

Indicator, liquid-level. Bulletin 6004V from Petrometer Corp. describes remote-reading liquid-level indicators with special "Aerator" valve. **Circle 145R.**

Mills, impact. Catalogs, data sheets, typical applications offered by Entoleter Div., Safety Industries, Inc. **Circle 116L.**

Mixers. Catalog A-27 from Philadelphia Gear Corp. contains complete mechanical design information. **Circle 15A.**

Mixers. Condensed catalog (Bulletin 109) from Mixing Equipment Co. gives details of all types. **Circle OBC-D.**

Mixers. General Bulletin from Turbo-Mixer Div., General American Transportation Corp. **Circle 81A-A.**

Mixers, batch. Catalog from Troy Engine & Machine Co. describes angular mixers, colloid mills, roller mills, unit blenders. **Circle 110TL.**

Mixers, portable ⅛ to 3 hp. Bulletin 108 from Mixing Equipment Co. **Circle OBC-C.**

Mixers, side-entering. 1 to 25 hp. Bulletin 104 from Mixing Equipment Co. **Circle OBC-E.**

Mixers, side-entering, propeller-type. Bulletin from Turbo-Mixer Div., General American Transportation Corp. **Circle 81A-C.**

Mixers, top-entering. Propeller types, ¼ to 3 hp. Bulletin 103 from Mixing Equipment Co. **Circle OBC-B.**

Mixers, top or bottom-entering. Turbine, paddle, and propeller types, 1 to 500 hp. Bulletin 102 from Mixing Equipment Co. **Circle OBC-A.**

Materials *from page 94*

Linings. Rubber or plastic linings put on odd shapes or special equipment. Details of service in Bulletin CE-53 from American Hard Rubber Co. **Circle 133R-B.**

Packing, Teflon. Bulletin 461 CEP describes Dura Plastic Teflon packing. Completely lubricated. Durametallic Corp. **Circle 122BR.**

Packing, Teflon. Technical data in Brochure from Flexrock Co. **Circle 153TR.**

Steel, stainless. Plates, rings, formed or cut-to-shape items. Data from G. O. Carlson, Inc. **Circle 107A.**

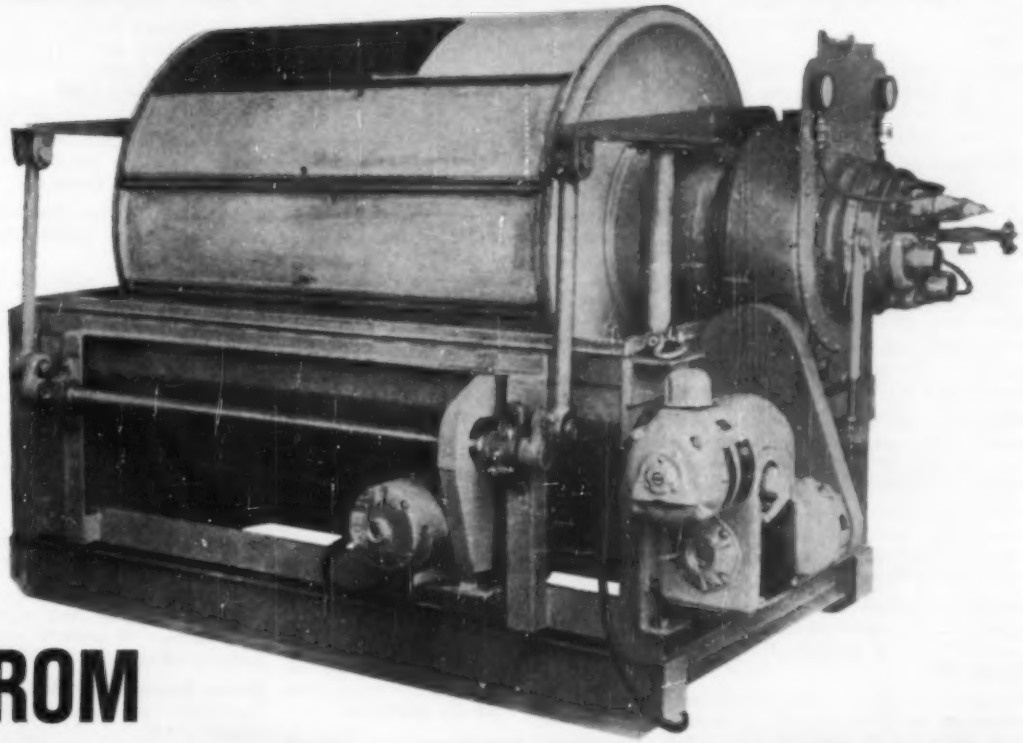
Steel, stainless-clad. Alloy and stainless-clad plates, fabricated steel products, large-diameter welded steel pipe. Data from Colorado Fuel and Iron Corp. **Circle 23A.**

Sulfur. Data from Texas Gulf Sulphur Co. on use of sulfur in insecticides and fungicides. **Circle 11A.**

Surfactants, nonionic. Bulletin from Union Carbide Chemicals Co. gives data on "Tergitol" nonionic surfactants for detergents. **Circle 17A-C.**

Zirconium and Titanium, high-purity. Data from U. S. Industrial Chemicals on new sodium reduction process for production of high-purity zirconium and titanium. **Circle 137-138A-A.**

FIRST MOLDED PLASTIC ROTARY FILTER



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It's the first commercially successful filter available with all essential components fabricated of a wide variety of glass reinforced plastics. Plastic selected is dependent entirely upon application.

Plastic construction results in lower cost than rubber-covered or alloy metal machines of comparable size and design. Reduced weight means economies in structural requirements, rigging and transportation. Apart from corrosion-resistance, the plastic surfaces offer special advantages where scaling is a problem, thus cutting maintenance costs. Snap-out rubber drainage grids provide for easy inspection and replacement.

The new Dorr-Oliver plastic filter has already been thoroughly tested handling acid leach solutions in a large uranium mill. It is backed by the long experience of Dorr-Oliver in building all types of filters. Models are available with filtering areas from 9 to 100 sq. ft. and 3-ft. and 4-ft. diam. drums with faces from 1 to 8 ft. For more information, write to Dorr-Oliver Incorporated, Stamford, Connecticut.

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CEP's DATA SERVICE—Subject guide to advertised products and services

Equipment *from page 96*

Packers, vibrating. For boxes, cans, cartons, kegs, drums, barrels up to 750 lb. Bulletin 401 from B. F. Gump Co. **Circle 3R.**

Piping, plastic. In high-impact rubber plastic, "Ace-lte." In sizes from ½ to 6 in. Valves ½ to 2 in. Bulletin 80A from American Hard Rubber Co. **Circle 133R-A.**

Piping, Teflon-lined. Bulletin TS-1A from Resistoflex Corp. gives performance data on Fluoroflex-T Type S piping systems. **Circle 129A.**

Potentiometer, portable. Weight less than 4 lb., accuracy ¼ of 1% of scale range. Bulletin 64-V from Thermo Electric Co. **Circle 134BR.**

Potentiometer, recording. Small, 5-inch model available with 2 pens, both recording full scale. Technical data from Westronics, Inc. **Circle 146R.**

Power Drives. Bulletin 965 from Pfaudler Co. describes the type W drive. **Circle 147A-A.**

Preheaters, air. Brochure from Air Preheater Corp. describes case history of fuel savings with Ljungstrom air preheater. **Circle 87A.**

Pumps, controlled-volume. Bulletin 440 from Lapp Insulator Co. gives flow charts, specifications, typical applications. **Circle 105A.**

Pumps, corrosion-resistant. Summary of acid and chemical pump data in Bulletin 203-7 from Lawrence Pumps, Inc. **Circle 120L.**

Pumps, diaphragm, controlled-volume. Pressures to 1,000 lb./sq. in., capacities from 1.1 to 138 gal./min. Data from Milton Roy Co. **Circle 36A.**

Pumps, gear, steam-jacketed. Full details in Bulletin 17-A from Schutte and Koerting Co. **Circle 145TL.**

Pumps, glassed. Temperatures to 350°F on all acids except hydrofluoric. Capacities to 700 gal./min., heads to 140 ft. Bulletin 727.3 from Goulds Pumps, Inc. **Circle 91A-B.**

Pumps, leakproof. Temperatures to 1,000°F, pressures to 5,000 lb./sq. in. **Circle 103A.**

Pumps, process. Consulting services available from Aldrich Pump Co. on any pumping problem. **Circle 113A.**

Pumps, vertical, centrifugal. For dangerous liquids, temperatures of minus 320 to plus 550°F, capacities to 800 gal./min., heads to 300 ft. Bulletin 727.2 from Goulds Pumps, Inc. **Circle 91A-A.**

Rectifiers, semi-conductor. Two bulletins from General Electric: Bulletin GEA-6684, semiconductor rectifier power conversion systems for electrolytic processes; Bulletin GEA-6375A, semiconductor power rectifiers. **Circle 84-85A.**

Rotameters. Bulletin 18L from Schutte and Koerting Co. gives details of laboratory rotameters. **Circle 152BL.**

Screener, portable. For powders, liquids, and slurries in meshes from 4 to 400. Technical data and prices from J. M. Lehmann Co. **Circle 144B.**

Separators, air. For use in closed-circuit with grinding mills. Nine models, diameters from 3 to 18 ft. Bulletin 087 from Sturtevant Mill Co. **Circle 142R.**

Separators, entrainment. Improve performance of distillation equipment, scrubbers, evaporators. Technical data from Otto H. York Co. **Circle 4A.**

Separators, entrainment. For efficient extraction of liquid from gas, steam, or air. Data from Peerless Mfg. Co. **Circle 32A.**

Sight Glasses, Pyrex. In 8 thicknesses, sizes up to 24 by 60 in. Bulletin from Swift Glass Div., Swift Lubricator Co. **Circle 145 BL.**

Steam Traps. Book from Armstrong Machine Works gives complete selection, maintenance, and installation data. **Circle 13A.**

Sublimer. Detailed technical information from Wyssmont Co. on the "Turbo-Entrainer" Sublimer. **Circle 99A.**

Tanks, storage. Standard designs from 500 to 5,000 gals. in stainless steel. Bulletin and price information from Hubbert. **Circle 152BR.**

Tank Tops. Special cone roof design eliminates corrosion maintenance problems. Technical details from Graver Tank & Mfg. Co. **Circle 6A.**

Thermometers, dial. Complete Catalog 205 from United States Gauge. **Circle 108L.**

Towers, packed. Technical data from U. S. Stoneware on metal and ceramic towers, tower accessories, tower packings. **Circle 38A.**

Valves. Complete catalog from Annin Co. describes full line of process valves and operators. **Circle 26A.**

Valves. Folder from Cooper Alloy Corp. —"Design Factors in Stainless Steel Valves." **Circle 111A.**

Valves, process. All types, from stock or specially-engineered for unusual conditions. Wm. Powell Co. **Circle 29A.**

Vessels, corrosion-resistant. Data from Ellicott Fabricators, Inc. on new "Novelon" linings of cement, rubber, lead, copper, plastic. **Circle 90L.**

Waste Disposal Systems. Complete information from Dempster Brothers, Inc. **Circle 115A.**

Water Treatment Plants. Available in unit sizes from 1 to 5 million gal./day. Complete with automatic controls. Full details from Hardinge Co. **Circle 28L.**

Weighers, continuous. Technical data in Bulletin 958 from Stephens-Adamson Mfg. Co. **Circle 12A.**

CEP's DATA SERVICE — Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 95

EQUIPMENT

301 Analyzer, oxygen, continuous. New Bulletin from Mine Safety Appliances Co. describes new model analyzer with automatic calibration.

302 Analyzer, process stream, chromatographic. Continuous model for in-plant use. Samples, analyzes, records. Bulletin from Davis Instruments.

303 Barrel Handler. Brochure from Vac-U-Lift Co. describes new barrel-handling unit operating on vacuum principle. Can be attached to fork trucks.

304 Blowers, rotary positive. Eight-

continued on page 100

MATERIALS

371 Catalysts. Expanded Catalog from Chemical Products Division, Chemetron Corp., lists all Girdler catalysts, both stock and experimental, gives technical details on all types.

372 Catalyst, hydrogenation. New, nickel-on-kieselguhr catalyst for selective hydrogenation of carbon-to-carbon double bonds of vegetable oils and animal fats. Technical data and samples from Girdler Catalysts, Chemetron Corp.

373 Caustic Soda. New Handbook from Stauffer Chemical Co. has charts on

continued on page 100

SERVICES

387 Design and Construction. Bulletin from Stearns-Roger Mfg. Co. gives details of its design, engineering, fabrication, construction, and testing services for cryogenics, nuclear engineering, high-pressure systems.

388 Design and Construction, iron ore reduction plants. Brochure from M. W. Kellogg gives details of new HyL process for direct reduction of iron ore, operating data from existing plant in Mexico.

389 Fabrication, process equipment. Four-page Booklet from Chicago Bridge

continued on page 100

CONTINUOUS SUBLIMATION

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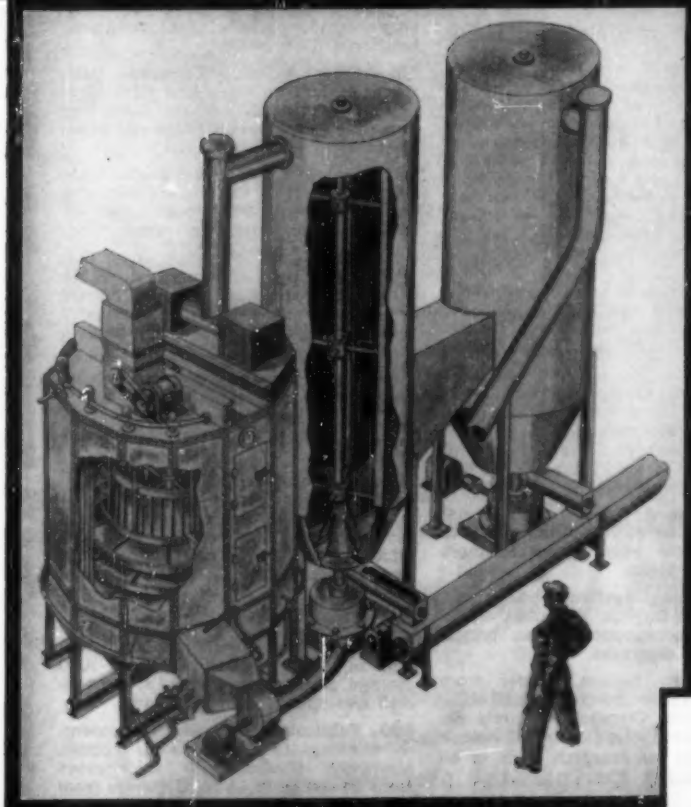
TURBO-ENTRAINER SUBLIMER



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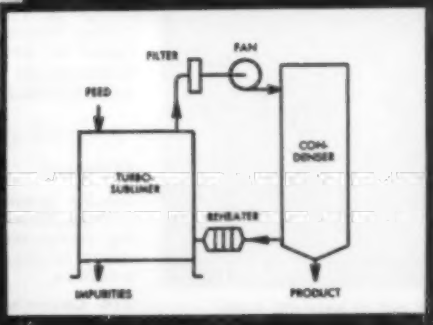

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CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 93

Equipment

from page 98

page Bulletin from Roots-Connersville Blower gives capacities, pressure ratings, design information.

305 Centrifuges. Bulletin from Pfaudler Co. gives technical details, process applications of the Titan Superjector.

306 Compressors, centrifugal, single-stage. Capacities from 1,200 to 80,000 cu. ft./min., input horsepowers from 10 to 2,500 bhp. Complete details in Bulletin from Clark Bros. Co.

307 Computers, digital. Application Report from Royal McBee Corp. describes use of the LGP Electronic Digital Computer in creating heat exchanger designs.

308 Controls, automatic. Bulletin from Swartwout Co. describes the "Thermo-Drive" actuator which operates on the basis of the controlled rate of heat release of Freon.

309 Controls, liquid-level. Bulletin from Magnetrol, Inc., describes many types of electric and pneumatic models.

310 Controls, liquid-level, electrode-type. Catalog from Charles F. Warrick (32 pages) gives principle of operation, specifications, application diagrams.

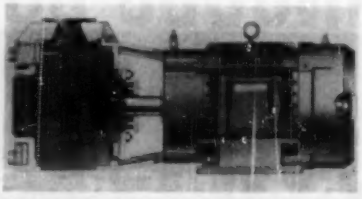
DEVELOPMENT OF THE MONTH

CATALOG OF FLANGES AND FITTINGS

(Circle 602 on Data Post Card)

A 135-page hard-cover catalog of flanges and welding fittings is offered free by OTM Corp. Covered are forged steel flanges, seamless long welding necks, orifice unions, API flanges, reducing flanges, ring joint gaskets, seamless welding fittings. Included are complete tables of dimensional tolerances, conversion factors, thread standards. For a copy of this handbook, Circle 602 on Data Post Card.

DEVELOPMENT OF THE MONTH



LARGE CAPACITY GRAPHITE PUMPS

(Circle 603 on Data Post Card)

Three new sizes of corrosion-resistant centrifugal pumps—two with nearly twice the capacity of present models—have been added to National Carbon Co.'s line of Karbate impervious graphite pumps. The two larger models can deliver up to 150 gal./min., as compared to a top of 80 gal./min. for previous type F Karbate pumps. Maximum total head for each of the three new types is 33, 51, and 67 ft., respectively. For technical data, performance curves, and prices, Circle 603 on Data Post Card.

312 Controls, temperature, recording. Available in 10 optional temperature ranges within the extremes of minus 30 to plus 1,100°F. Data from Partlow Corp.

314 Controls, timing, explosion-proof. Designed in accordance with Underwriters Laboratories standards for hazardous locations of Class I, groups C and D, and Class II, groups E, F, and G. Catalog from Industrial Timer Corp.

315 Conveyors, chain. For bulk material conveying at temperatures up to 932°F. Bulletin from Buhler Brothers Engineering Works.

316 Conveying Systems, pneumatic. Bulletin from Day Co. describes equipment and accessories, gives typical arrangement diagrams.

317 Cryostat, helium. Folder from Arthur D. Little describes the ADL-Collins Helium Cryostat, uniquely designed for production of liquid helium temperatures for research work in all scientific fields.

continued on page 102

Materials

from page 98

specific gravity of solutions, dilution and heat generation calculations, freezing temperatures, solubility and viscosity ranges, boiling points, heats of solutions.

374 Cements, magnesium oxychloride. Technical Data Sheet from Westvaco Mineral Products Division, Food Machinery and Chemical Corp. gives specifications, reactions, uses.

375 Chemicals, industrial. Chemical Products List from Hooker Chemical Corp. gives chemical formula, physical data, uses, types of container for 65 industrial chemical products.

376 Chemicals, industrial, New, 64-page Catalog from Antara Chemicals, General Aniline & Film, lists surfactants, organic intermediates, acetylene derivatives, carbonyl iron powders, ethylene oxide, glycols, etc.

377 Chemicals, industrial. Product Catalog gives properties and uses of 375 industrial, pharmaceutical, and agricultural chemicals. Dow Chemical Co.

378 Coatings, acrylic emulsion. New, 60-page Book from Rohm & Haas Co. gives data on formulations and exposure tests. Many tables and photos.

379 Dimethyl Ethers. New 23-page Catalog from Ansul Chemical Co. gives physical and chemical properties, specifications, applications, suggested uses. Extensive bibliography.

380 Fluoroalcohols. Technical data from Du Pont on three new fluoroalcohols with potential uses in producing high fluorine content organic intermediates.

381 Insulation, refractory. Folder from Pittsburgh Corning Corp. gives technical data on Foamsil, 99% pure fused silica, practical operating range from minus 450 to plus 2,200°F.

382 Jacketing, aluminum. Available with factory-attached moisture barrier or with chemical-resistant "Arocoat." Bulletin from Performed Metal Products Co.

383 Methyl Borate. Callery Chemical Co. offers technical data and prices on methyl borate—methanol azeotrope, now available in commercial quantities.

384 Nitrogen Derivatives, fatty. Complete specifications on five groups of fatty nitrogen derivatives. Applications as petroleum additives, corrosion inhibitors, chemical intermediates. Data from General Mills Chemical Division.

Services

from page 98

& Iron Co. describes engineering, fabrication, and erection services. Also storage and pressure vessels, Horton-clad and special alloy structures.

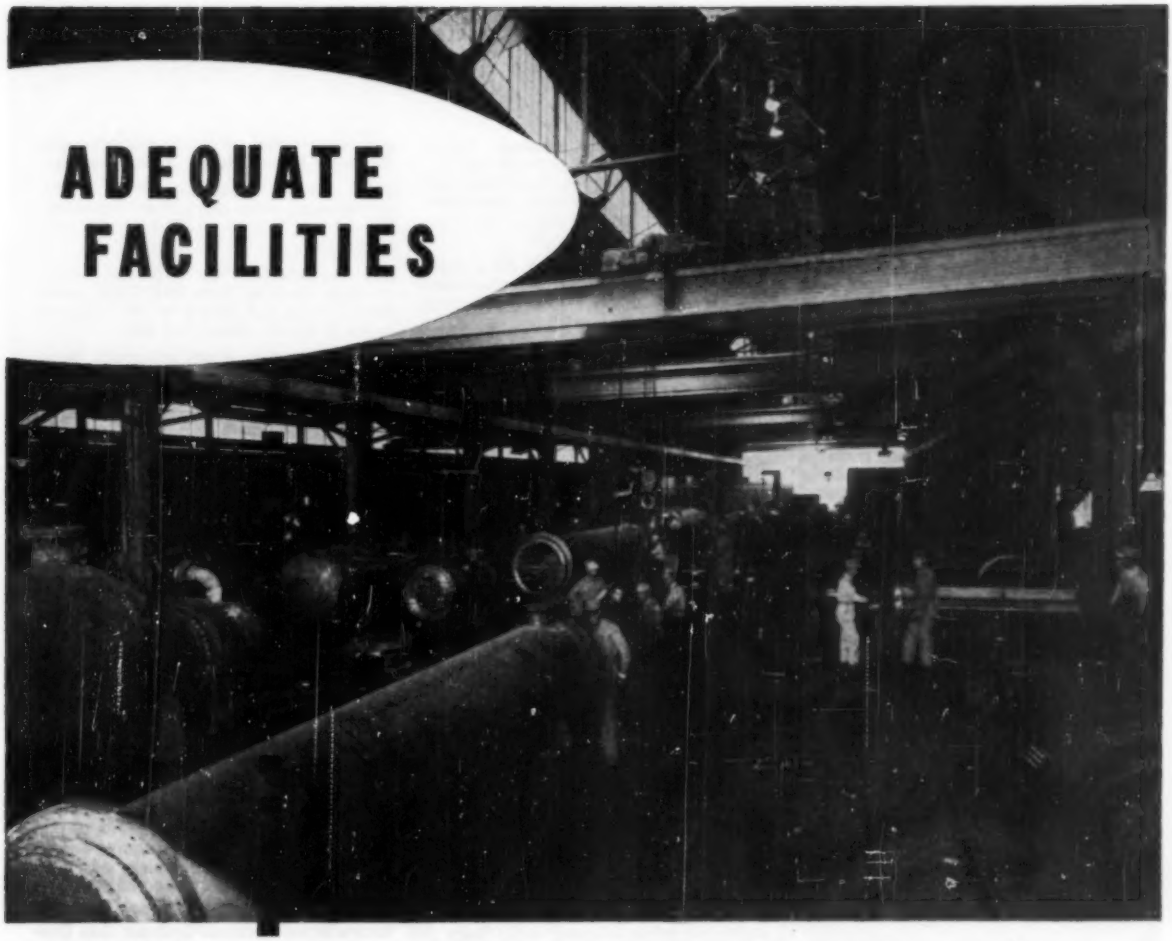
390 Fabrication, process equipment. In stainless, Monel, nickel, Inconel, Hastelloy, titanium, in thicknesses from 24 gauge to ½ in. Brochure from Alloy Products Corp.

391 Fabrication, process equipment. Pressure vessels, fabricated assemblies in steel and alloys to all codes. Bulletin from Fitzgibbons Boiler Co.

392 Fluids Analysis Service. Fischer & Porter Co. offers laboratory facilities for calibration of flow measuring devices, determination of fluid properties such as density, viscosity, consistency, shear stress.

393 Particle Size Table. Handy, pocketsize sliding table shows particle size correlations from 2,000 microns down to 1 micron. Diameters in inches related to U. S. Standard, Tyler, and British Standard screen sizes.

394 Tank Capacity Calculator. Slide rule calculator determines capacity and size of storage tanks up to 100 ft. high, 300 ft. diameter. Hammond Iron Works.



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CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 95

Equipment

from page 100

318 Cyclones. Apex designs and controls for Krebs Cyclones featured in new Brochure from Equipment Engineers. Cut-away drawings and apex capacity chart.

319 Dialysis Equipment. New dialysis system, developed by Graver Water Conditioning Co., said to contain first acid-resistance membranes. Technical data.

320 Equipment, carbon and graphite. Catalog Section from National Carbon Co. describes complete line of carbon and graphite equipment for chemical processing.

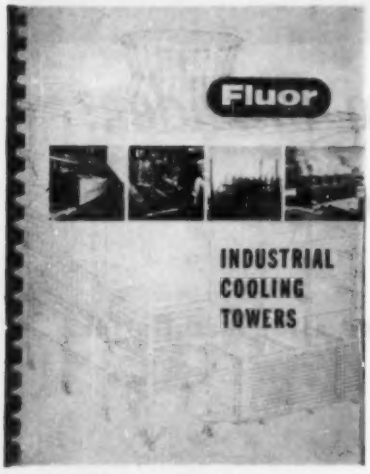
321 Equipment, pilot plant. Bulletin from Artisan Metal Products describes stills, distillation equipment, evaporators, recovery units, reactors.

322 Equipment, processing. Brochure from Graham Mfg. Co. describes steam jet ejectors, condensers, evaporators, deaerators.

323 Equipment, processing. Bulletin from Ertel Engineering Corp. gives details of filters, bottle fillers, pumps, mixers.

324 Equipment, processing. Condensed Catalog from Sprout-Waldron gives details of equipment for size reduction and classification, mixing and blending, materials handling, pelleting and densifying, digesting.

DEVELOPMENT OF THE MONTH



COOLING TOWER BOOKLET
(Circle 601 on Data Post Card)

Exhaustive brochure from Fluor Products Co. gives design and fabrication details of counterflow induced-draft cooling towers. Fluor towers are completely prefabricated for speed and ease of erection and minimum cost. Component parts are fabricated in modules of six ft. by six ft. in the horizontal plane, and eight ft. vertically. The brochure describes in detail structural components, sheathing, packings, water distribution system, fan stacks, and speed reducers. Circle 601 on Data Post Card.

325 Equipment, processing. Eight-page Brochure from Hardinge Co. describes equipment for agitating and mixing, pelletizing, clarifying, classification, grinding, cooling, drying, filtering, feeding.

326 Equipment processing. New, comprehensive Catalog from Southwestern Engineering Co. describes complete line of heat exchangers and pressure vessels. Specifications and selection charts.

327 Equipment, processing. Read Standard, Division of Capitol Products Corp. offers complete Catalog of mixers, filters, materials handling equipment, structural equipment.

328 Equipment, processing. Size reduction equipment for fine, medium, and coarse grinding, batch and continuous mixing and blending. Bulletin from Strong-Scott Mfg. Co.

329 Equipment, processing. Specialized equipment for ion exchange, sedimentation, filtration, flotation. Bulletin from Graver Water Conditioning Co.

330 Equipment, processing, corrosion-resistant. New 4-page Catalog from American Agile Corp. details corrosion-resistant fabrications and coatings, components, semi-finished materials, fabricating equipment, laboratory ware.

331 Equipment Components, unplasticized PVC. Bulletin from Stokes Molded Products has 3-page tabulation of chemical resistance of unplasticized PVC.

332 Feeders, vibratory. High-capacity electromagnetic models, rates from 25 to more than 1,000 tons/hr. Technical data from Syntron Co.

333 Filters, cartridge-type. Catalog from Cuno Engineering Corp. gives selection chart, cartridge life curve, flow rate table, performance data.

334 Filter Medium, metallic. For filtration, straining, distribution, dispersion. Bulletin from Multi-Metal Wire Cloth Co.

335 Flowmeters, turbine-type. Available for pressures to 5,000 lb./sq. in., temperatures from minus 455 to plus 1,000°F. Bulletin with complete specifications from Cox Instruments Div., George L. Nankervis Co.

336 Gauges, pressure, high-precision. Technical bulletin from Wallace & Tiernan describes new dual-bourdon tube gauges which allow high-precision readings to 500 lb./sq. in.

337 Heat Exchangers, graphite. Carbone Corp. offers technical information on three new standard models of the "Polybloc" graphite heat exchanger. Flows up to 84,000 gal./hr.

338 Heat Exchangers, stainless steel. Specifications on 19 standard models available in one-, two-, and four-pass design. Bulletin from American-Standard, Ross Heat Exchanger Division.

339 Instruments, analytical, automatic. Complete assemblies designed and constructed for automatic analysis. Brochure from Chicago Apparatus Co.

340 Joints, expansion, PVC. Fully-guided even when completely extended. Sizes from ¼ to 4 in. Data from Walworth Co.

341 Laboratory Ware, plastic. New, 16-page Catalog from Will Corp. gives descriptions and prices on 78 different types of plastic laboratory ware.

342 Laboratory Ware, porcelain. New, 75-page Catalog from Kern Laboratory Supply Co. shows complete line of Haldenwanger porcelain ware, made in West Germany.

343 Meters, liquid-level. The Tank-O-Meter permits measurement of tank contents from any desired remote point. Bulletin from Uehling Instrument Co.

344 Mixers, rotary batch. Available in stainless steel, hot-rolled steel, or vinyl-coated steel drums. Brochure from Munson Mill Machinery Co.

345 Motors, weather-protected. In ratings from 250 to 2,000 hp. Full specifications in Bulletin from Louis Allis Co.

346 Packings, Teflon. Bulletin from Chemical & Power Products, Inc., lists Teflon packings, gaskets, bearings, seal cages, mechanical seals, other pump and rotating equipment parts.

347 Piping, corrosion-resistant. Bulletin from Fibercast Co. contains 4-page table on chemical resistance of Fibercast 300 pipe, other selection data.

348 Piping, gas. New, 28-page Brochure from National Cylinder Gas Division, Chemetron Corp., describes duplex, simplex, and portable manifold distribution systems.

349 Piping, impervious graphite. Data from Falls Industries on complete corrosion-proof piping systems composed of standardized pipe lengths and fittings.

350 Piping, plastic, Flexible polyethylene pipe can handle highly corrosive fluids at low pressures at temperatures up to 150°F. Data from Carlon Products Corp.

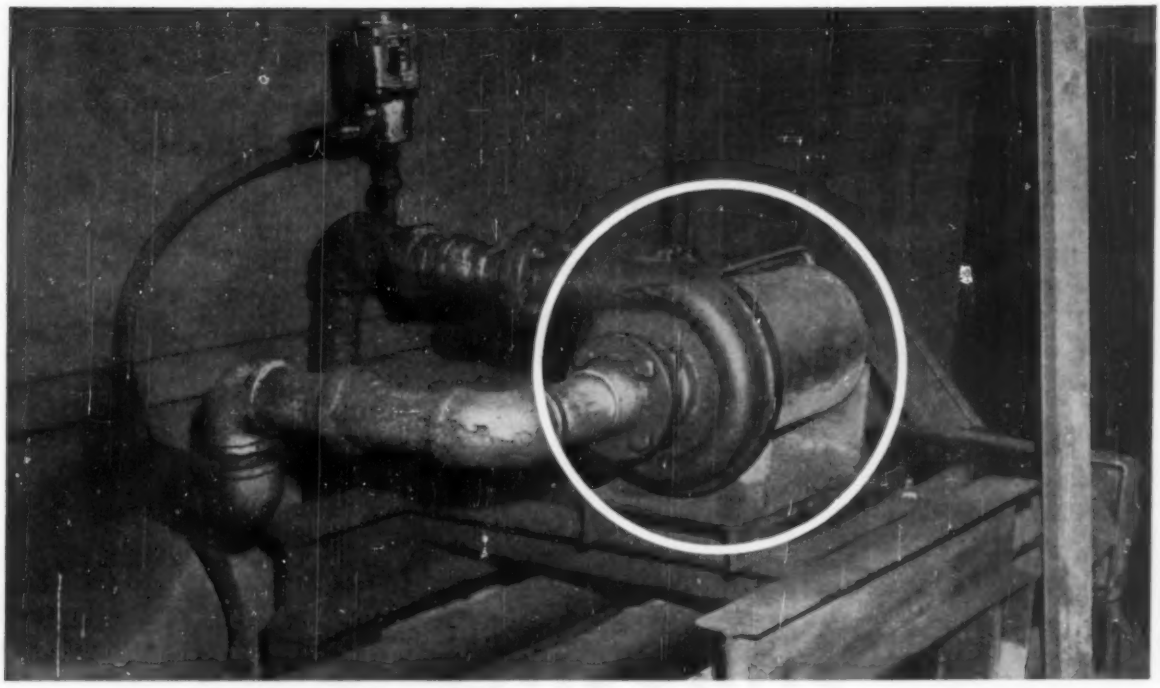
351 Processor, agitated-film. For concentration of viscous, foamy, or heat-sensitive materials. Bulletin from Buflovak Equipment Division, Blaw-Knox, describes the "Roto-Vak."

352 Processor, high-vacuum. Technical Bulletin from Rodney Hunt Machine Co. describes the "Vacu-Film" processor and its applications to chemical processing.

353 Pumps, controlled-volume. Application Engineering Data Sheet from Milton Roy Co. describes use of controlled-volume pump in two-stage continuous chlorine drying system at Hooker Electrochemical Co.

354 Pumps, diaphragm. Available in single and double-stage models, specially designed to handle corrosive liquids. Schweitzer Equipment Co.

continued on page 104



Chempump gives leak-proof service

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This *Chempump* circulates oil through the heat exchanger of an electric furnace power transformer. It was installed at one of the world's most modern foundries in September, 1955. *It has required no maintenance to date.*

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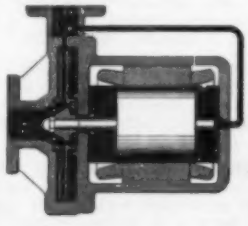

Chempump combines pump and motor in a single, leak-proof unit. No shaft sealing device required.

U.L. approved. Available in a wide choice of materials and head-capacity ranges for handling fluids at temperatures to 1000 F. and pressures to 5000 psi.

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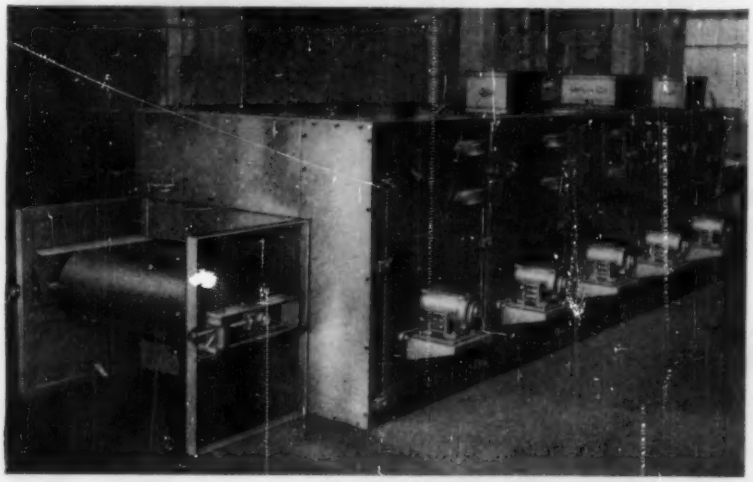

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Equipment

from page 102

355 Pumps, diaphragm, adjustable-stroke. From 1 in. simplex to 10 in. duplex, capacities from 2½ to 1,000 gal./min. Full details in Bulletin from Denver Equipment Co.

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358 Rotameters. Bulletin from Brooks Rotameter Co. gives technical details of "Full-View" rotameters.

359 Rotameters, by-pass. For measuring rate of liquid or gas flow in pipelines 2 in. or more in diameter. Bulletin from Schutte and Koerting Co.

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367 Valves, midget. New Catalog from High Pressure Equipment Co. gives details of full line of midget valves and fittings, used to provide minimum capacity in capillary and small-diameter high-pressure tubing systems.

368 Valves, for nuclear reactors. For primary and secondary system and instrumentation control. Details in bulletin from Automatic Switch Co.

369 Valves, plastic-lined. In cast iron or aluminum bodies lined with Penton, new Hercules Powder plastic (chlorinated polyether). Technical Information Bulletin from Hills-McCanna Co.

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Solid propellant applications —New opportunities

R. A. Cooley, *Propellex Chemical Corp.*

Progress in the development of solid propellants has increased interest in a number of new, non-military applications. Cartridge actuated devices now make greatest use of the propellants, but wider application is anticipated.

Without any break-throughs toward improving the intensive properties of propellants now available, there are still new opportunities in solid propellant applications. Significant development effort in the field of solid propellants in the United States dates from about 1942. Military financed development work on solid propellants for rockets and missiles has provided an extensive library of propellants which can be produced relatively safely with reproducible properties. Military financed projects have also provided fairly effective testing, instrumentation, and design procedures. The propellants currently on the shelf have a wide variety of properties, such as burning rates, which may vary over a 600 fold range, e.g. from .01 in. per second at 1000 lb/sq. in. to 6 in. per second at 1000 lb/sq. in. The specific impulses vary from 150 seconds to 260 seconds. Flame temperatures of propellants may be depressed to below 1000°F., and uncontrolled could reach 4500°F. In some designs the physical properties of propellants are such that they can withstand 10^5G's acceleration. Efforts to manufacture propellants so that they will have a high degree of reliability and reproducibility during ignition and deflagration have been successful. Some of the highest performance propellants are expensive, but much can be done with the older and lower priced propellants.

Today, experienced engineers can develop propellant-actuated devices quickly and cheaply aided by the theory of design developed by government financed rocketry. To develop superior propellant actuated devices, it is necessary to

1) select the right chemical composition from the propellant library,
2) choose the best geometrical design of propellant grain,
3) select or develop a suitable igniter,
4) place them in a properly designed envelope, and
5) carry out enough testing to refine design and prove reliability.

It is also helpful to understand cartridge design and the internal ballistics of guns and rockets.

Because engineers are gradually recognizing the high degree of reliability which may be expected from properly designed propellant devices, and since miniaturization of complex systems is a constant demand, a large number of new devices are using solid propellant.

Prodigious power generation per unit weight and volume can be supplied by solid propellant or explosive energized devices. Propellants may be ignited by an electrical or percussion means, and their rate of energy generation can exceed 500 horsepower even when less than one ounce of propellant is used. A propellant actuated device may be considered to be a high-gain power amplifier in that a very small amount of input energy is required to initiate the propellant.

Table 1

Criteria for recognizing new propellant applications

1. Is a compact power source required?
2. Can the power required be derived from propellant gas over an acceptable period of time?
3. Is a rapid rate of power delivery required?
4. Can propellant reduce or eliminate electric, hydraulic, or pneumatic requirements with their electric cords, hydraulic tubing, or air hoses, thus allowing an overall weight reduction, increased convenience or a system simplification?
5. Is the power source subject to severe environmental conditions, e.g. vibration, shock, extreme temperature cycling, salt spray, and fungus?
6. Is the power source stored for a long time to be suddenly put into operation for a comparatively short time?

Input to propellant devices

The input to a propellant powered device may be mechanical or electrical.

Fig. 1 shows a design of primer which is stab actuated. Penetration of the firing pin through the sealing disc

continued on page 108

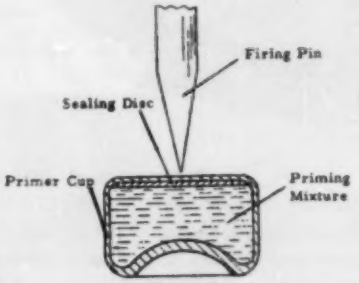


Figure 1.

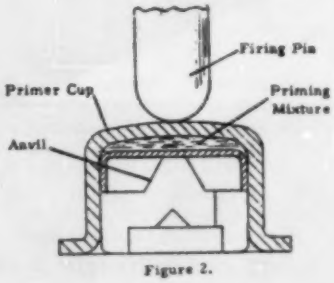


Figure 2.

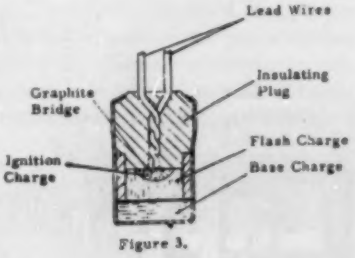


Figure 3.

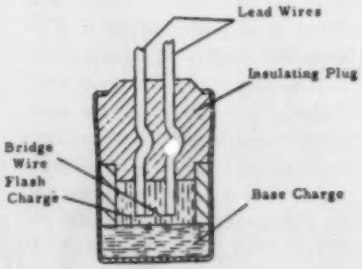
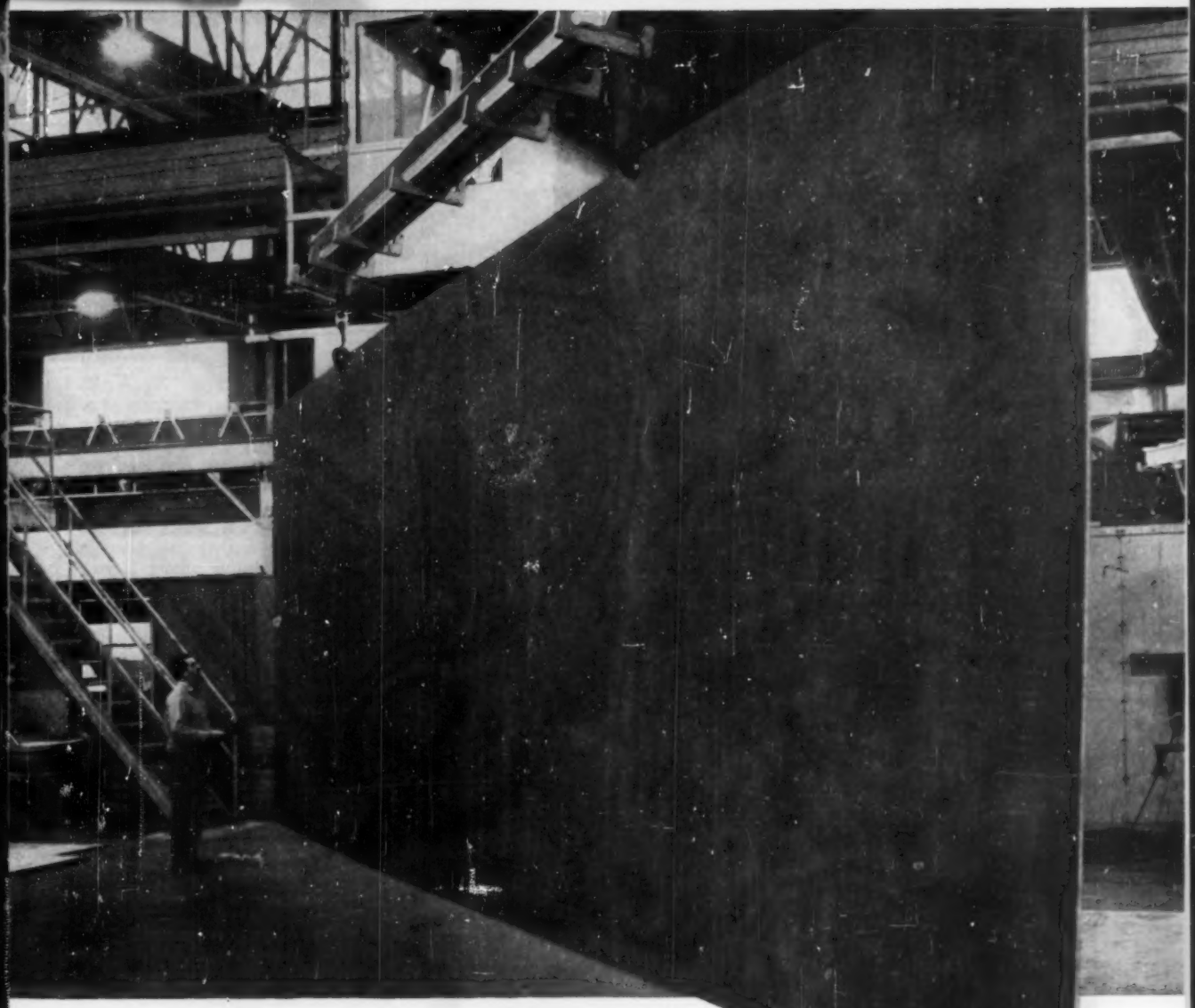


Figure 4.

(Courtesy Naval Ordnance Lab)

Typical primer designs now used.



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Solid propellants

from page 106

initiates a reaction which leads to ignition of solid propellant. Fig. 2 depicts a percussion primer. Here the firing pin impact starts the primer. Fig. 3 illustrates an electrical primer with a graphite bridge. Electric current passing through the graphite bridge initiates a sensitive chemical contiguous to the bridge. Fig. 4 presents the details of a bridge wire type electrical primer. In this primer the bridge wire heats to a high enough temperature to initiate the sensitive chemical coating the bridge wire. One of the newest types of primers is a propellant system which may be actuated by aerodynamic heating. The chemical in this primer is very insensitive to impact but auto-ignites at about 350°F. The input required to ignite a propellant may consist of a base charge followed by a flash charge, or a graphite bridge and ignition charge may be used. Diazo dinitrophenol, potassium chlorate and lead styphnate have been used for base charges.

The amount of energy necessary for the input of a primer is very significant. If it is too small, it may cause a safety problem as the static electricity generated by persons who handle them may initiate them. Primers can be developed which require an input energy as small as 100 ergs. A primer such as this could start a conventional high explosive train which would liberate as much as a million times the energy of the original primer.

Since initiation of primer materials is dependent on rate of energy input, less energy is required when it is supplied at higher voltages. The length to diameter ratio for bridge wires is not important unless the wire becomes so short that end effects become significant. The normal bridge wire in a primer has a resistance between one and twenty ohms. However, if one uses a carbon or graphite bridge, the resistance is generally either 750 ohms or 15,000 ohms. Conductive mixes for primers have a resistance between one and 800 million ohms.

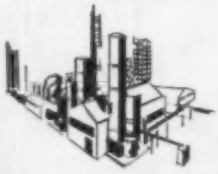
Output of propellant devices

In the output of propellant energized devices, the pressure achieved can be up to 100,000 atmospheres. The flame temperatures can be of the order of 4,500°F. The mean molecular weight of propellant gases is about 28. The units can operate in the absence of oxygen and even under water if desired. The chemical com-

continued on page 110

For handling tough corrosives in the production of urea

The Grand River Chemical Division of

DEERE & Company  uses DURCO pumps, valves, filters

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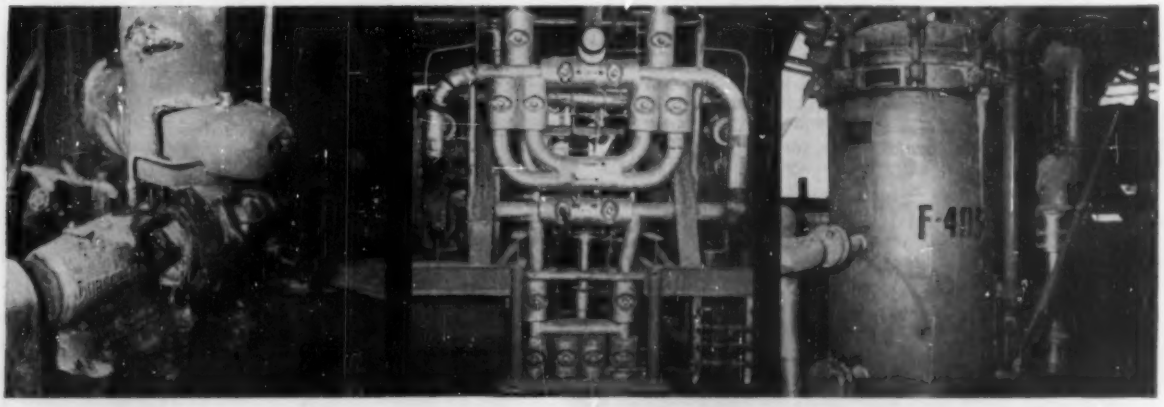

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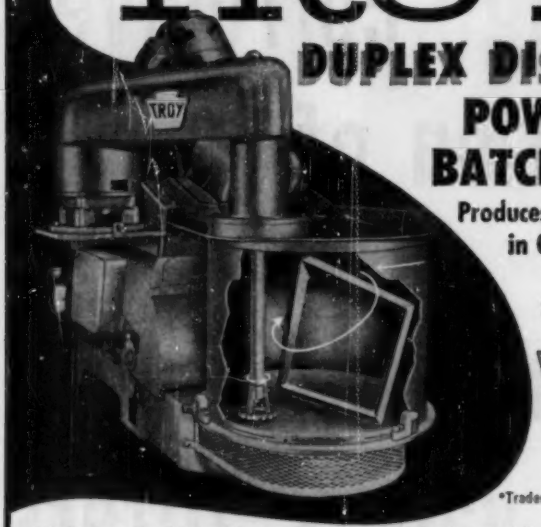

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Solid propellants

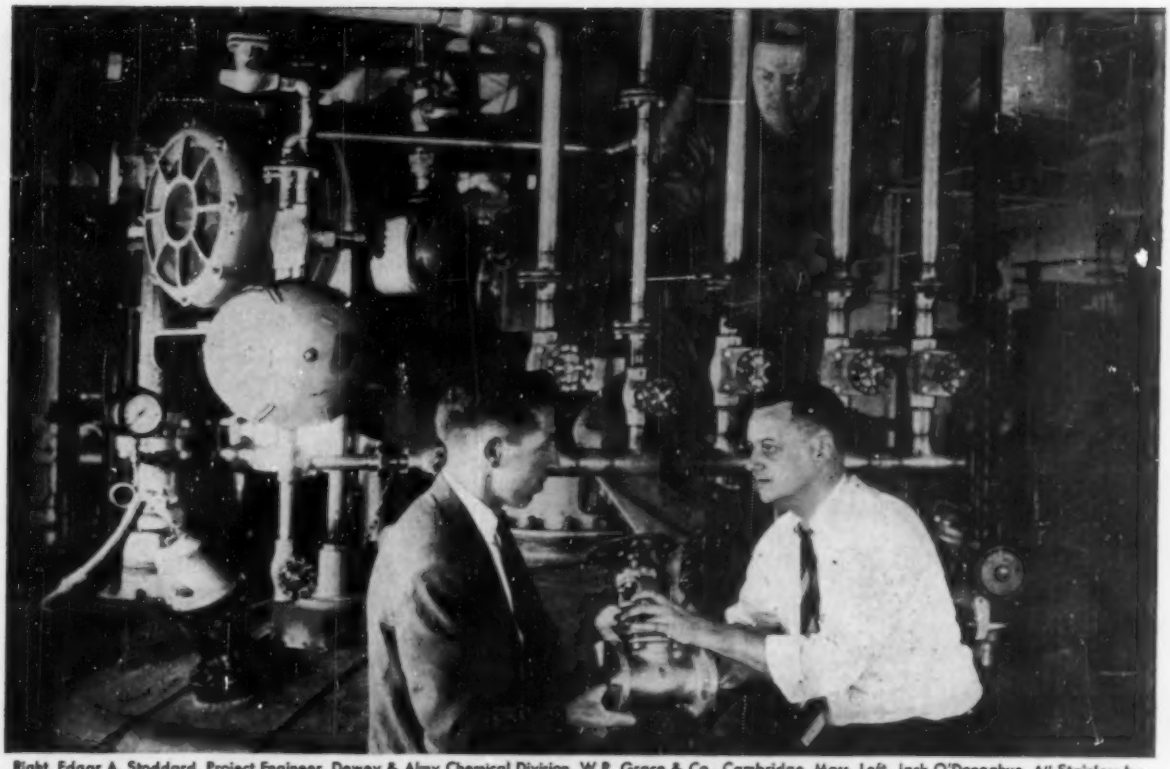
from page 108

position of exhaust gases can be varied considerably, e.g. by changing from ammonium nitrate as oxidizer to ammonium perchlorate. For solid propellants a representative number of moles of gas evolved per gram of propellant is about .05.

Since a propellant grain can be designed with the use of an inhibitor to provide a varying but selected burning surface area, the mass rate of gas production from the grain can be in accord with a preselected program. Thus, desired complex pressure versus time curves in a closed or leaking system can be assured. Generally, an accurate prediction of the resistive forces against which the propellant gas is working is needed for design purposes, but pressure regulators can sometimes be used to insure a given pressure-time history when the resistive forces are not predictable.

Table 2
Some Applications of Solid Propellant

1. Cutters or Guillotines
   - a) Metal
   - b) Metal cable
   - c) Fiber lines (parachute reefers and risers)
   - d) Non-metal hose
2. Thrusters
   - a) Aircraft canopy removers
   - b) Separators of thrust stages
   - c) Brakes
   - d) Pilot seat and stores ejection systems
   - e) Spike actuators for pilot escape systems
   - f) Electric switches
   - g) Rocket thrust terminators
   - h) Weight lifters (jacks)
3. Gas Generators
   - a) Starting turbojet engines
   - b) Electric power generator
   - c) Hydraulic pump driver
   - d) Inflaters
     1. Emergency rafts
     2. Helicopter pontoons
     3. Pilot seat ejectors
     4. Caterpillar dimple or bellows motors
     5. Sub-satellite balloons
     6. Fire extinguisher pressurizers
     7. Cartridge percussion pin actuators
     8. Oil well cementers
   - e) Emergency landing gear and brake actuator (aircraft and automotive)
4. Explosive Bolts
5. Zero Leak Valves
6. Safing and Arming Devices (temperature and non-temperature sensitive)
7. Metal Forming
8. Acoustic Signals



Right, Edgar A. Stoddard, Project Engineer, Dewey & Almy Chemical Division, W.R. Grace & Co., Cambridge, Mass. Left, Jack O'Donoghue, All Stainless Inc., Cooper Alloy distributor, Allston, Mass. Background, C. W. Stuart of Thomas G. Gallagher, Inc., Somerville, Mass., contractors.

STODDARD of DEWEY & ALMY

Tells Why He Specifies Cooper Alloy for Stainless Valves and Fittings

Q. Mr. Stoddard, why does Dewey & Almy, a leading manufacturer of chemical and plastic specialties for industry, use stainless valves and fittings?

A. For two reasons of major importance in the chemical processing industry: purity of product, and resistance to corrosion.

Q. Why Cooper Alloy?

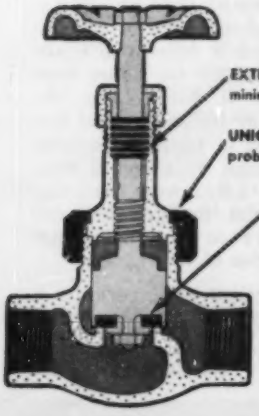
A. For three reasons equally important: ease of maintenance, thanks to Cooper Alloy's unique design features; availability; and distributor service.

Q. What design features are you referring to?

A. Well, take these Cooper Alloy renewable-disc globe valves on these monomer lines. We like the ease of operation and low maintenance. And of top importance, these valves eliminate serious vapor leakage we once had.

Q. What about availability and service?

A. Outstanding. In fact, All Stainless Inc., the local Cooper Alloy distributor, has even gone to the trouble of taking over most of our stocking problems, by putting in a complete representative stock of Cooper Alloy RD globe valves. That's what we call *service!*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"I suspect that Italian engineering education, with all of its encumbering tradition, its exhausting examination system, its emphasis on theory, its divorcement from practical problems, and its lack of laboratories, has more qualities in it essential for success in the development of great minds than are found in present American engineering education."

One man's opinion, to be sure—that of J. O. Maloney of the University of Kansas who recently spent a year teaching chemical engineering in an Italian university on an exchange basis. However, in the midst of the present "agonizing reappraisal" of our scientific educational system, with its impassioned pleas for quality, quantity, or both at the same ttime, it is probably the part of wisdom not to brush off any point of view too easily, and to investigate in depth the educational systems of our Western European friends and allies as well as that of our Communist adversaries.

Italian education, continued Maloney, is not a "democratic" system, for the State is committed to a program of early testing to separate the able students from the ineffective. A student's career depends primarily upon his ability to perform in school.

In France, and in England too, a very rigid system is used at an early age to sort out those scholars considered capable of higher education. Aaron Rose of Olin Mathieson, recently Fulbright lecturer in chemical engineering at the University of Nancy, quotes a French professor—"In the United States, you make the selection after the university; here in France, we make the selection before the university."

Rose had the distinct impression that the French university graduate enters industry at a much higher level than do our graduates. Our new graduates, he says, are expected to prove themselves. In France, the new graduate has already proved himself, in that he has completed the really grueling years of university and secondary school work.

Successive selection of top students starts in the English school system when children reach the age of eleven years, reports J. E. Myers of Purdue, Fulbright lecturer in chemical engineering, 1956-1957, University of Leeds, England. At this age, the children are given examinations which determine whether they will be permitted to enter grammar school at public expense. A grammar school education is almost mandatory if a student wishes to gain university entrance. Thus, a student who is admitted to a university and finally receives a university degree is likely to be a person of appreciable academic skill. He will have had an expensive education, since 75% of all university students hold tax-supported scholarships, and he should be capable of considerable achievement.

Academic independence

The management and operation of each Italian university is in the hands of its full professors, emphasizes Maloney. In Italy, the route to a professorship rarely includes a period of full-time industrial experience. The route lies within the universities. But, the men appointed to professorships are selected not only for their position in their own fields, but also for their general knowledge and national stature. It is expected that they shall serve as consultants to industry, or as directors on boards of large corporations, or even as members of the Italian parliament.

In Maloney's opinion, however, the examination system in the Italian universities "stops any serious educational work in the university." Out of a typical school year, about fourteen weeks are spent in examinations. In general, attendance is not required in any course, no assignments are made in it, and the student takes the examination when he feels ready to do so.

The Italian chemical engineering curriculum is nominally five years long, but actually takes seven years, on the average, for completion. No subjects outside of science and technology appear in it, except a course in law. Compared to an American curriculum, it has about two more years of work in science and technology. The result is that their engineering education is more broadly established in all branches of engineering. But, there are other less appealing aspects to it. Laboratories in engineering where undergraduates regularly do experiments seem to be minimal or non-existant. Furthermore, most of the subjects we consider ideal for teaching in a quantitative manner, using numbers and demanding numerically correct answers, are frequently taught to Italian students in theoretical form. Exercises are not the order of the day, and the examination in the course is the usual twenty-to-sixty-minute oral.

Strength and weakness

There are several great sources of strength in the Italian university, sums up Maloney. Only intelligent well-trained students enter the university. Only men who are productive scholars can hope for a professorial post. Another source of strength is the emphasis placed on theory throughout the courses in science and engineering.

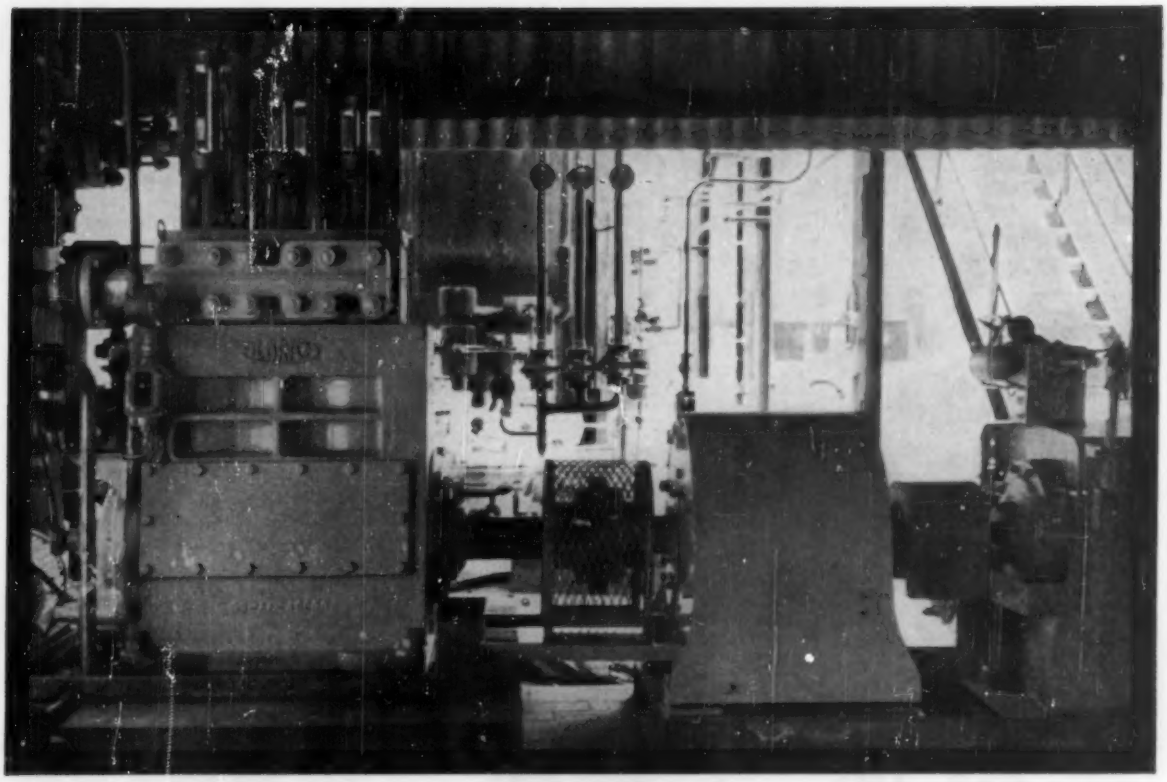
A number of weaknesses are evident in the Italian university. The examination system wastes everyone's time: it places lectures, class attendance, and numerical exercises in subordinate roles; and it fails to give any realistic preparation for future engineering work. "I doubt," says Maloney, "that any Italian chemical firm is uninterested in numerical calculations, encourages its chemical engineers to present their work when they feel like it, and, finally, bases company decisions on a twenty-minute oral examination of its engineers."

French chemical engineering

There have been for many years, points out Rose, schools of industrial

continued on page 114

Material in this article has been adapted from three papers given at the Chicago National Meeting, A.I.Ch.E., at a symposium on Chemical Engineering Abroad:
Chemical Engineering in Great Britain, J. E. Myers, Purdue University.
Chemical Engineering in France, Aaron Rose, Olin Mathieson Chemical Corp.
Traditional Aspects of Chemical Engineering Education in Italy, J. O. Maloney, University of Kansas.



THE PRESSURES ARE HIGH...THE LIQUIDS CORROSIVE...THE PUMPS ARE ALDRICH...

At the Houston plant of Rohm & Haas Co., this Aldrich pump alternately introduces caustic and brine into one phase of the acrylate process for producing acrylic monomers.

The problem: Handle highly corrosive liquids at 3000 psi in a continuous process and *not* have severe maintenance problems.

What Rohm & Haas did about it. Company engineers specified Aldrich 1⅝" x 5" stroke Triplex Pumps for three reasons.

1. Compact, heavy-duty construction makes Aldrich pumps ideal for high pressure service.

2. Aldrich pumps are designed for easy maintenance. Fluid-end sectionalization permits quick removal of valves for inspection or replacement. No special tools are required.

3. Aldrich engineers can draw upon a vast store of experience when it comes to selecting the right materials for any pumping job. In this case, the entire fluid end . . . working barrel, suction and discharge manifolds . . . are forged Monel. Valve seats are Haynes Stellite. Valves and plungers are K Monel.

Results: According to the Plant Manager of the Houston plant, "maintenance requirements have decreased and pumping production improved. These Aldrich pumps lend themselves to easy maintenance."

How Aldrich can help you. Solving pumping problems like this requires specialized engineering skills and experience. We have those skills, and our experience comes from years of working with the chemical industry. We welcome the opportunity to discuss your specific problems . . . no matter what the liquid or how high the pressures. Aldrich Pump Company, 3 Gordon Street, Allentown, Pa.

the toughest pumping problems go to ALDRICH

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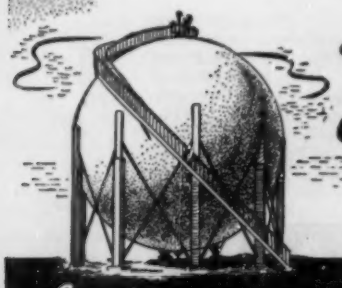
Specify Aerofin and you specify high efficiency, long service life and low maintenance and service costs.

Take advantage of Aerofin's unequalled experience, production facilities, and materials-testing and design research — of Aerofin's complete engineering service at the plant and in the field.

* *Aerofin makes extended heat surface exclusively — not as a by-product, not as a side-line.*



Throughout the Chemical Industry —

Aerofin units do the job Better, Faster, Cheaper

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European engineer

from page 112

chemistry as integral parts of the various French universities. The profession of industrial chemist, as opposed to a more academic type of chemistry, is a well-known one in France, and in many of the universities there are separate faculties in which industrial chemistry is taught. In addition, there are specialized schools for certain industries which teach chemical engineering.

In the French Lycee, the students have what we usually refer to as humanities, as well as a strong mathematical preparation, so that when they are ready to enter the university, they will take only technical courses.

There are three main differences, says Rose, between chemical engineering as we know it in the United States and as it is taught in France. First, there is the question of the order in which information is presented to the student. Traditionally, in France, all the various industries are described in the industrial chemistry courses. Here, in the U. S., we study the basic operations which are common to these industries, and afterwards the various combinations which cover all of the work done in our American chemical industry. The second big difference is the importance given to what the French refer to as industrial physics. Here, physical chemistry plays an extremely important role; this refers not only to physical chemistry courses as such, but also to "offshoots" such as thermodynamics, stoichiometry, etc., which we study in chemical engineering. In France, such courses are much less important. A third difference, is the question of quantitative teaching in engineering. In the United States, a considerable emphasis is placed on problems. In the French tradition, more emphasis is placed on theory.

British teaching methods

With two exceptions, says Myers, the undergraduate programs in chemical engineering in England are three-year programs. The other two require four years. The three-year program may seem short when compared with American courses, which can scarcely be crowded into four years. However, the students entering university engineering departments in England have all had calculus, and most have had differential equations. In addition, the English students will have completed a considerable amount of chemistry, and will have had the equivalent of

continued on page 116

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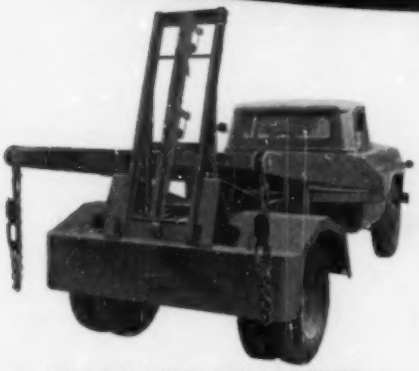

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America's Most Complete Line of Waste Disposal Systems

The big savings in waste disposal are made with mechanized, containerized, collection equipment. Dempster Brothers, the pioneer manufacturer of containerization equipment, now offers four efficient systems to help you increase your efficiency and decrease costs.

The DEMPSTER-DUMPSTER handles containers up to 15 cu. yds. The DEMPSTER-DUMPMASTER, available in three sizes, picks up and empties containers from one through six cu. yd. capacity. Compaction bodies are 18, 24 and 30 cubic yards with capacities up to 120 cubic yards of loose refuse. The DEMPSTER Compaction Trailer will hold and haul over 200 cubic yards of loose material per trip and it can be loaded by the DEMPSTER-DUMPSTER GRD-304-F-2. The DEMPSTER-DINOSAUR offers giant containers up to 40 cu. yds. and over. Write today for complete information.

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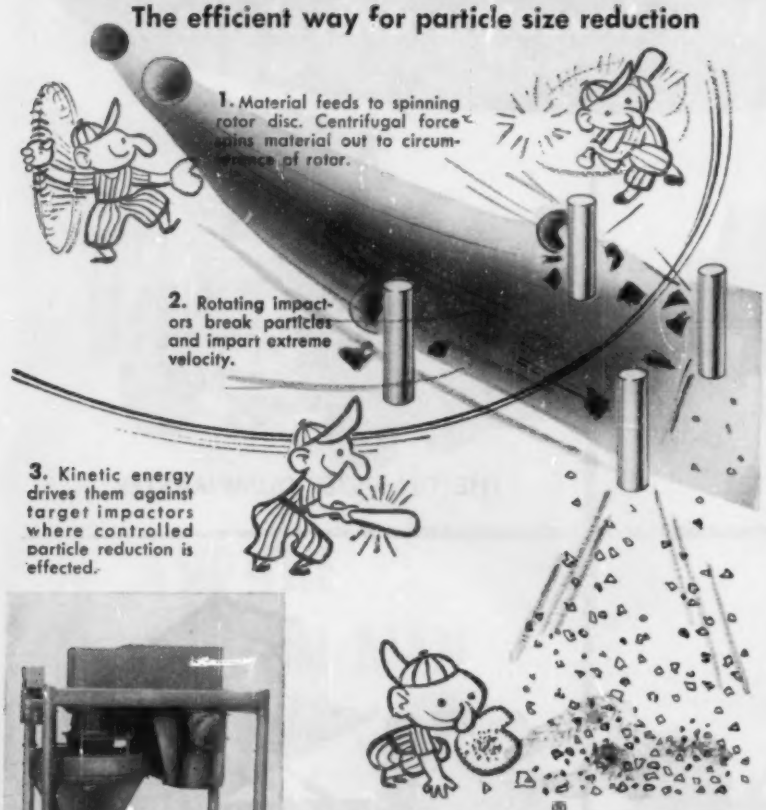
The efficient way for particle size reduction


1. Material feeds to spinning rotor disc. Centrifugal force spins material out to circumference of rotor.
2. Rotating impactors break particles and impart extreme velocity.
3. Kinetic energy drives them against target impactors where controlled particle reduction is effected.

APPLICATION:

Freeing *POLYETHYLENE* pellets from clustered mass without mutilation or temperature rise.

Entoleter Centrifugal Machines (Series 27 shown above) handle processing of entire output of Polyethylene Pellets for one of the country's largest producers.

Low cost, low power requirements and high capacities plus precise control of result make impact mills ideal for many chemical processing applications.

HERE'S WHY THE ENTOLETER® IMPACT MILL DOES A BETTER GRINDING OR MIXING JOB!

- Initial cost, operating cost and Maintenance cost are *lowest* of any production grinding method.
- Handles many times the capacity per horsepower — wet or dry.
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***FREE** test runs of your materials.*

European engineer

from page 114

one year of American college physics.

Methods of teaching in England are somewhat more formal than in America. Courses consist mostly of lectures without much use of problem assignments. The shortage of problem solving is generally compensated for to some extent by the assignment of a rather extensive design problem in the senior year. This problem requires between 150 and 300 hours or work, and includes process and equipment design as well as economic calculations. Each report must include working drawings of some of the mechanical details.

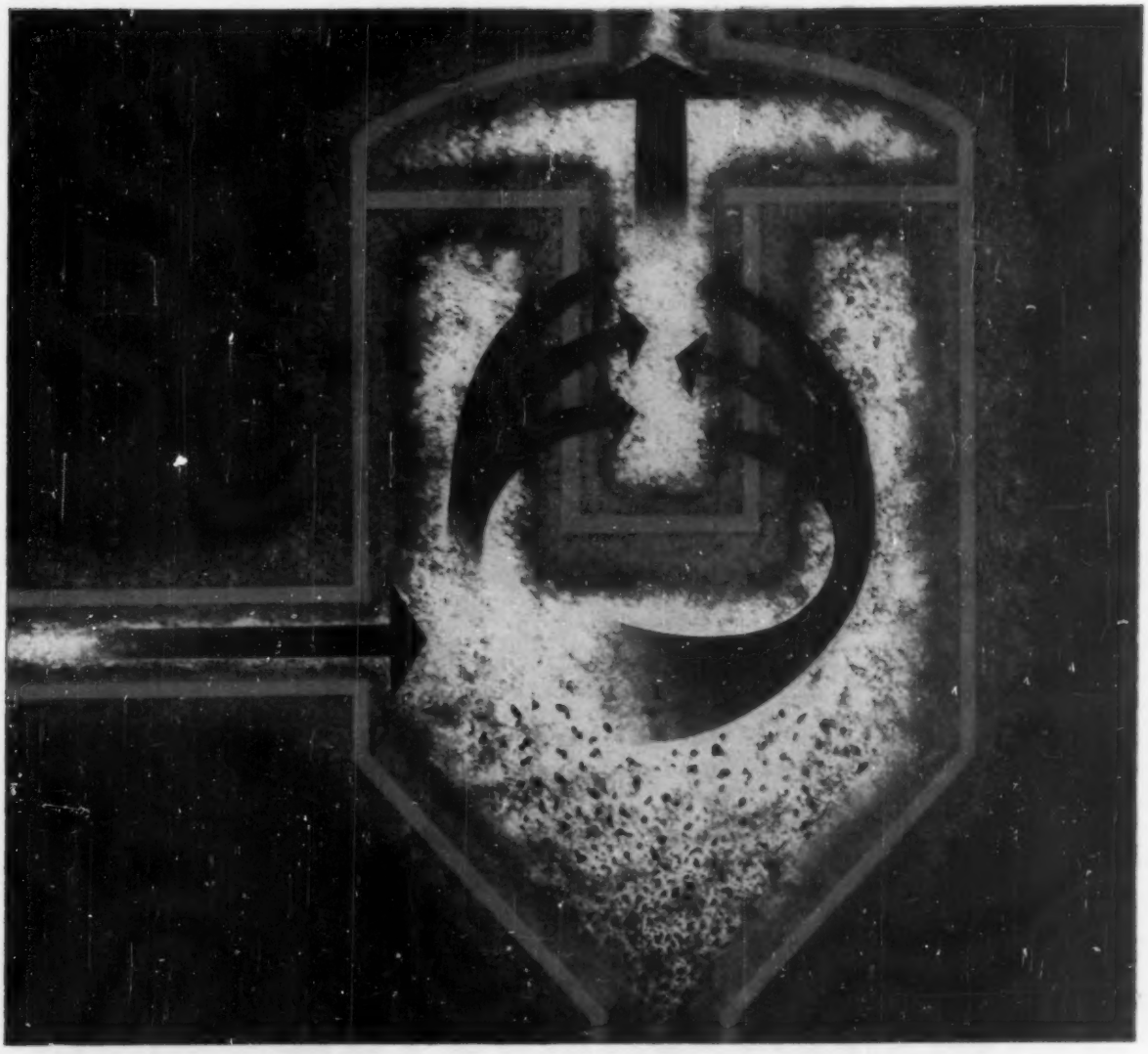
Students in Britain take the usual unit operations laboratory courses that are offered in America. An interesting part of the training in most schools is the requirement that a summer be spent in some chemical industry.

The goal of every British student is, or should be, a first-class honors degree. The class of the degree awarded is determined almost entirely by the student's performance in the final examinations of his senior year. A first-class degree in chemical engineering carries great distinction, and gives the student exemption from military service if he is to be employed in industry or as a teacher. A second-class degree is also quite respectable, and makes the graduate eligible for employment by the government in certain fields such as atomic energy.

A new vinyl emulsion polymerization plant is under construction at Toronto, Canada, for National Adhesives (Canada) Ltd. Initial capacity will be 5 million lb. annually, provision is being made for expansion to 8 million lb. Target date for start-up is March, 1959, engineering is by Laughlin, Wyllie and Ufnal, Toronto.

Methylamine capacity has been doubled at the new (1957) plant of Commercial Solvents at Terre Haute, Indiana.

Ultramarine blue pigments and allied chemicals manufactured at Cologne, West Germany, by Vereinigte Ultramarin Fabriken A.G., will be marketed in the U.S. by a newly-formed subsidiary, United Ultramarine & Chemical Co. Additional stated function of the new company will be to maintain contact with the American chemical industry to develop licensing agreements for German manufacture of specialty chemicals.



Filters for extreme conditions

HIGH HEAT *plus* CORROSION

Processing Uranium Hexafluoride by gaseous diffusion.

Operating at a temperature so high (over 1200°F) that the filter and its housing are red hot, this specially designed and constructed Purolator frameless metal edge filter reclaims fines from the highly corrosive gas.

The extreme heat and the corrosive gas are necessary for the process . . . Purolator's problem was to come up with the filter which could do the job required under these conditions. The filter, constructed of monel, combines a porous metal facing on a frameless metal edge element. It has been in constant operation since its installation.

Difficult jobs like this are made to order for Purolator. Designing and producing filtration equipment to meet exacting demands requires the combination of engineering skill and manufacturing know-how only Purolator offers.

Two brochures outline what Purolator can do for you on your toughest filtration requirements. They're both yours for the asking. Write to Jules Kovacs, Vice President in charge of Technical Sales. If you have an urgent filtration problem *now*, send Mr. Kovacs the details of it.

Filtration For Every Known Fluid **PUROLATOR**

PRODUCTS, INC.

RAHWAY, NEW JERSEY AND TORONTO, ONTARIO, CANADA

The Philadelphia-Wilmington Section, A.I.Ch.E., has awarded a Certificate of Recognition for Outstanding Service to **A. S. West,** group leader in the Process Design Section of Rohm and Haas. From 1956 to 1958, West served as chairman of the Membership Committee of the Section. At present, he is serving as vice-chairman for the Industrial Section and for the Northern Division of the Educational Section of the National Membership Committee.

R. R. Paxton has been appointed chief engineer of the Pure Carbon Co., St. Marys, Pa.

The Institute of Paper Chemistry has elected **Roy P. Whitney** as an additional vice-president. Whitney joined the Institute in 1947 as head of the chemical engineering group. He became dean in 1956, and will continue to hold that office.

Dwight Jeffrey has been named production superintendent at General Tire & Rubber's Odessa, Texas, synthetic rubber facility. Jeffrey was formerly general foreman at General's Mogadore, Ohio, chemical plant.

Allied Chemical has appointed **James G. Fox, Jr.,** as executive vice-president, and **J. Warren Carey** as a vice-president of its National Aniline Division.

Paul E. Graybeal named superintendent of Hercules Powder's Hopewell, Va., plant. Since 1956, Graybeal has been assistant superintendent of the company's Hattiesburg, Miss., plant.

George J. Sella, Jr., has been appointed a product manager in American Cyanamid's rubber chemicals department. He will be in charge of commercial development of antioxidants and chemicals for the synthetic rubber industry.

New process design engineer in Ethyl Corp.'s Research and Development Department in Baton Rouge is **Robert E. C. Weaver.**

The U. S. Public Health Service has awarded a $24,955 research contract to **Seymour Calvert,** associate professor of chemical engineering, Case Institute of Technology, to study the effects of wet scrubbers for air pollution control.

James E. Stice, formerly assistant professor at the University of Arkansas, has been appointed instructor in chemical engineering at Illinois Institute of Technology.

Warren L. McCabe, administrative dean of Brooklyn Polytechnic Institute, has been elected vice-president of the Engineers' Council for Professional Development (ECPD). Before coming to Brooklyn Polytechnic in 1953, McCabe had been vice-president and director of research for the Flintkote Co., Whippany, N.J.

New staff additions at Sun Oil's Research and Development Laboratory, Marcus Hook, Pa., are **Albert T. Oleniczak,** in process development, and **E. Allen Blair,** in basic research.

The Electro Chemicals Division of Diamond Alkali has appointed **T. S. Dewoody, Jr.,** to the newly-created position of manager, technical staff. Dewoody joined the Diamond organization in 1947 as superintendent of its chlorine-caustic soda plant at Pine Bluff Arsenal.

Recipient of the Industrial Research Institute Medal for 1959 is **Frank K. Schoenfeld,** vice-president, research, of B. F. Goodrich Co. The medal is given annually to honor "outstanding accomplishment in leadership in, or management of, industrial research which contributes broadly to the development of industry or the public welfare."

Edgar E. Wrege, formerly leader of the Experimental Engineering Section of American Viscose's Research and Development Division, has been placed in charge of systematic project evaluation for that division. In his new capacity, Wrege will "combine the technical and commercial possibilities of existing and proposed research programs."

Ralph M. Gifford has joined the production staff of Chas. Pfizer & Co. Gifford will do chemical development work at the company's Groton plant.

Russell L. Miller, manager of Monsanto's John F. Queeny Plant in St. Louis, has been named manager of labor relations for the company's Organic Chemicals Division. In the Inorganic Chemicals Division, St. Louis, **Michael P. Mauzy** becomes a group leader in the research department. Also at Monsanto, **Richard N. Augustson** joins the development department of the company's Overseas Division as area development manager for Latin America.

Dale O. Cooper and **Louis P. Karvelas** have joined the consulting firm of Bonner & Moore Engineering Associates, Houston, Texas. Cooper comes to Bonner & Moore from Union Oil Co., where he worked as process design and economic engineer, while Karvelas was previously employed by Humble Oil & Refining as an engineer in the petrochemical economic evaluation section, and as a cost engineer.

Wayne C. Edmister has joined the staff of Oklahoma State University as professor of chemical engineering. Edmister, who returned to Oklahoma State on leave from an engineering research position with California Research Corp., was last year's winner of the Richards Memorial Award of ASME.

J. E. Moise, assistant director in the field of chemicals, has moved to the office of Refinery Liaison of Esso Research and Engineering, Linden, N.J. **J. A. Polack,** presently assistant director in the field of personnel and business administration, succeeds Moise. Also at Esso Research and Engineering, **L. E. Swabb, Jr.,** has been appointed assistant director, and **W. J. Porter, Jr.,** has been advanced to section head.

Atlas Powder has appointed **Herbert L. Jones, Jr.,** as senior chemist in the product development department of its Chemicals Division. Jones comes to Atlas from the Mellon Institute where, since 1955, he has headed the Fibrous Material Fellowship.

Gilman S. Hooper has been named vice-president in charge of research, and **L. Louis Malm** as vice-president in charge of engineering at Industrial Rayon Corp.

The Illinois Institute of Technology has named **Octave Levenspiel** to the

continued on page 120

OPTIMUM DESIGN...

of YUBA HEAT EXCHANGERS achieved by COMPUTER SYSTEM

Into Yuba's Central Computer System go the temperatures and pressures your heat exchangers must handle, flow quantities and fluid properties, tube layout, allowable pressure drop, and nozzle connections.

Out comes the number in series, shell size, minimum number of segmental baffles, optimum number of tube passes, calculated pressure drop, heat transfer rate on both shell and tube sides, and the corrected LMTD. Elapsed time: 15-20 minutes with the computer as compared to days with the slide rule.

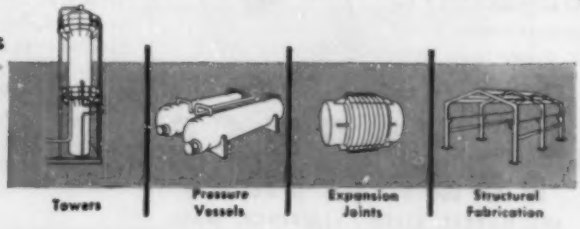
No guesswork! Optimum results with absolute accuracy. Also...we can extract from the Yuba Computer System all kinds of alternates for you: alternate flow quantities, alternate temperatures, and alternate tube construction (fin or bare). This central computer system is used by all Yuba divisions manufacturing heat exchangers.

YUBA HEAT TRANSFER DIVISION, Homedale, Pa.; ADSCO DIVISION, Buffalo, N. Y., and YUBA MANUFACTURING DIVISION, Benicia, Calif.

YUBA CONSOLIDATED INDUSTRIES, INC.

OTHER YUBA PRODUCTS FOR THE CHEMICAL AND PETROLEUM INDUSTRIES.

Plants and Sales Offices



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Lawrence 2-Stage Vertical Pump for Pumping Liquid Chlorine out of Tanks.

PUMPS to handle LIQUID CHLORINE

Pumping liquid chlorine calls for more ingenuity and engineering skill than is available from the average pump manufacturer. Formerly it was pumped pneumatically. This method was attended by a considerable loss of chlorine because the moisture in the air formed hydrochloric acid. A further complication was the corrosive action of the acid vapors.

To overcome this, Lawrence engineers in collaboration with manufacturers of chlorine, developed a pump with a special packing box which prevents any contamination of the chlorine or corrosion of any of the equipment and also prevents the escape of the chlorine fumes to the atmosphere.

For over 80 years Lawrence has been making pumps to handle every acid or chemical fluid used in industry. If you have a particularly difficult chemical pumping problem, we can save you both time and money. Write us the pertinent details, no obligation.

Send for Bulletin 203-7 for a complete summary of acid and chemical pump data.

LAWRENCE PUMPS

LAWRENCE PUMPS INC.

371 MARKET STREET, LAWRENCE, MASS

from page 118

position of associate professor in the Chemical Engineering Department.

Clark E. Thorp, formerly associated with Armour Research Foundation, Chicago, has been elected president of Fiber Products Research Center, Beaver Falls, N.Y.

A. W. Hogeland, formerly design engineer in American Viscose's Central Engineering Department in Philadelphia, has been transferred to the company's Film Division. Hogeland has been temporarily assigned as construction-design coordinator for the new Marcus Hook, Pa., cellophane plant.

Lewis C. Bowers and Sons, Inc., Princeton, N.J., announces appointment of **H. W. Boynton** as general manager of its Engineering Division. Since 1955, Boynton has been assistant director of research for Escambia Chemical Corp.

John W. Gaylord, formerly technical assistant to the manager of process research, has been named senior staff specialist—nuclear energy—at California Research Corp.'s Richmond Laboratory.

Appointment of **Edward P. Fleischer** as assistant to the president has been announced by Consolidated Electrodyanamics Corp.

Albert E. New has been named vice-president and director of production by Escambia Chemical Corp. New will have charge of the company's three plants near Pensacola, Florida.

John E. Wood (left), general manager of the Chemicals Products Department of Esso Standard Oil, will become president of Enjay Co. Wood has been with the company since 1939. At the same time, Enjay has named three new vice-presidents: **Karl J. Nelson,** who has headed up Enjay's Sales Department since July, 1958; **Harold J. Rose,** head of the Products Management Department; and **A. Donald Green,** in charge of the company's New Products Department.

New staff member of the Whiting Research Laboratories of Standard Oil (Indiana) is **Aivars Kuplis.** In his new post, Kuplis will carry out pilot-plant studies of petroleum refining.

Liggett & Myers Tobacco Co. has promoted **Max Samfield** from supervisor of engineering research to assis-

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News from
National Carbon Company
Division of Union Carbide Corporation • 30 East 42nd Street, New York 17, N. Y.
Sales Offices: Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco. IN CANADA: Union Carbide Canada Limited, Toronto

Marketing Manager, Chemical Products

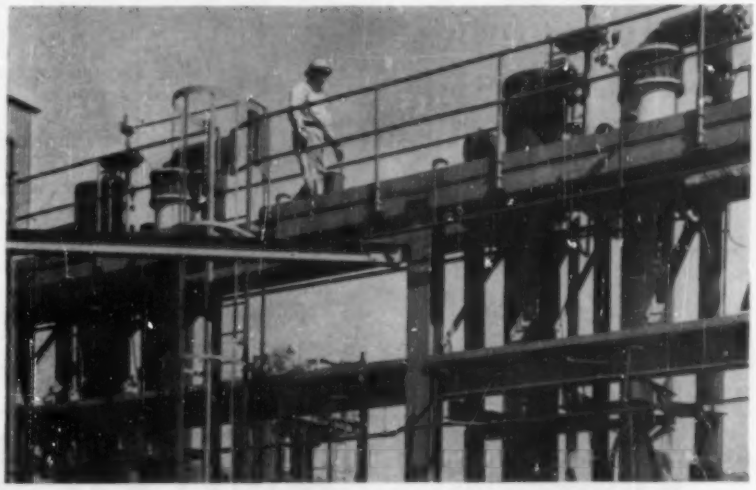
W. W. PALMQUIST

Mr. Palmquist was graduated from Yale University with a B.S. in Chemical Engineering. He has spent ten years preparing design proposals, developing new designs and improving existing designs of "Karbate" chemical processing equipment. Based on this extensive design and development background, Bill was made Manager of Sales Promotion and Development for the Chemical Products Sales Department.

For the past year, Bill has been Chemical Products Marketing Manager and is responsible for marketing the complete line of "National" carbon and graphite products and "Karbate" impervious graphite for the chemical processing and allied industries.

He is a member of the American Institute of Chemical Engineers, the National Association of Corrosion Engineers and the Electrochemical Society.

"KARBATE" CONDENSERS PROVIDE LONG, ECONOMIC LIFE IN CORROSIVE SERVICES



A bank of 4 "Karbate" condensers in an organic chemical plant.

10 to 15 Years of Trouble-Free Service

Eleven shell and tube heat exchangers have proved the excellent corrosion resistance of "Karbate" impervious graphite material. These exchangers have provided ten to fifteen years of trouble-free operation in condensing a highly corrosive *chlorinated hydrocarbon.*

Based on this performance record, additional "Karbate" shell and tube heat exchangers are planned for expansion and renovation programs in this plant.

"KARBATE" Condenser replaces Silver Condenser

To overcome the silver condenser problems of high-cost, specialized fabrication and exacting maintenance procedures, a "Karbate" shell and tube condenser was installed by a major chemical company in an *acetic anhydride* condensing application.

The unit is handling 80% *acetic anhydride* vapor at a temperature of 100°C.

The replacement "Karbate" impervious graphite unit has provided excellent heat transfer and examination after 20 months of service show it to be as good as new.

NATIONAL CARBON FABRICATES 20-FT. LONG "KARBATE" TUBE HEAT EXCHANGER

National Carbon Company was requested to replace a steel bundle in an existing all steel shell and tube heat exchanger. This presented a problem of 20-foot long tubes plus a two pass shell side arrangement. Photograph below illustrates the design of the "Karbate" baffle system used to reproduce the two pass shell feature. The 20 foot "Karbate" tube bundle was installed in the customer's existing steel shell and is now in service.

NATIONAL TRADE-MARK

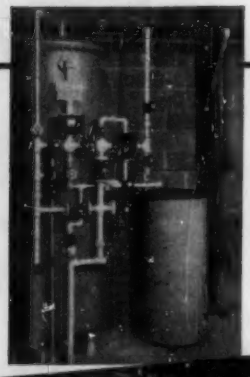
The terms "National", "Karbate", "N" and Shield Device and "Union Carbide" are registered trade marks of Union Carbide Corporation.

UNION CARBIDE

21¢ PER 1000 GALLONS FOR

Demineralized water better than

DISTILLED WATER



ELGIN
Single-Tank, Mixed-Bed
DEIONIZER

What are you paying for distilled or evaporated water? The Elgin Ultra-Deionizer has brought the cost of water, freer from mineral impurities than distilled water, down to the low price quoted above (based on 10 grain water).

It removes all ionizable impurities . . . including CO_2 and silica.

Low investment and operating cost.

Requires less space . . . thanks to exclusive "double-check" design.

ELGIN
WATER CONDITIONING
SINCE 1908

Write for Bulletin 512

Zeolite Water Softeners
Dealkalizers
Deaerating Heaters
Filters of all types
Water Conditioning Products for every need.

ELGIN SOFTENER CORPORATION
182 N. GROVE AVENUE • ELGIN, ILLINOIS

from page 120

tant director of research. Samfield will continue to supervise the company's Engineering Research Division.

Winner of the Achievement Award of the Chemical Specialties Manufacturers Association is **Emil G. Klarmann,** vice-president in charge of technical services for Lehn and Fink, Inc. Klarmann, who has been associated with Lehn and Fink for 34 years.

Erling Kløfstad has been elected president of Crosby Valve & Gage Co. and its affiliate, the Ashton Valve Co. Klafstad was formerly associated with Manning, Maxwell & Moore, Stratford, Conn., as assistant director of engineering.

Humble Oil and Refining has promoted **Thomas W. Pickel, Jr.,** from chemical engineer to senior supervising engineer in its Catalytic Light Ends Section, Baytown, Texas.

John D. Fennebresque elected president and chief executive officer of Texas Butadiene & Chemical, Houston, Texas. Fennebresque comes to Texas Butadiene from Food Machinery & Chemical, where he was an executive vice-president and a member of the board of directors. He has served on the chemical and rubber advisory committee of the Department of Commerce.

Robert H. Perry has resigned as project engineer with Scientific Design Co. to become associate professor of chemical engineering at the University of Oklahoma.

Two new managerial appointments are announced in General Electric's Insulating Materials Operation in Schenectady, N.Y. **J. C. Morris** becomes manager, Coated Materials and Irradiated Products, for Schenectady and Pittsfield, Mass., and **J. T. Rossello** will be manager, Mica Products Operation, for Schenectady and Coschocton, Ohio.

continued on page 124

DURA PLASTIC *Teflon* packing for chemicals

DURA PLASTIC
STYLE 666 F
Die-Molded Rings

DURA PLASTIC
STYLE 66 F
Spiral

A Completely Lubricated TEFLON PACKING

Durametallic's answer to sealing corrosive fluids—DURA PLASTIC *TEFLON* PACKING. It provides long uninterrupted sealing on all liquids except molten alkali metals and some flourine compounds in the higher temperatures. Particularly suitable for packing rods, shafts and stems on processing equipment handling hot caustics, acids, alkalies or organic solvents from -90°F. to 450°F. Supplied in die-molded ring or spiral form.

WRITE FOR DURA PLASTIC TEFLON PACKING BULLETIN 461 CEP

The PERFECT SEAL

DURAMETALLIC CORPORATION
KALAMAZOO MICHIGAN

LOW INSTALLATION COSTS BEHIND

CB&I — BUILT

EVAPORATOR-CRYSTALLIZER

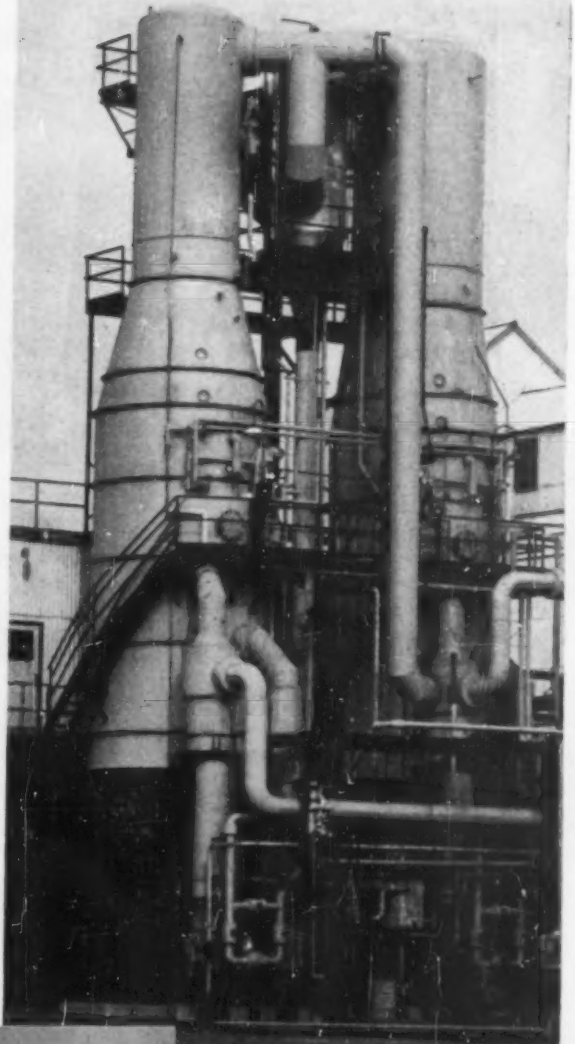
producing Ammonium Sulfate for
National Aniline Division

This double effect, evaporator crystallizer is used to produce crystelline ammonium sulfate and recover caprolactam monomer, raw material for Caprolan, (Allied Chemical's polyamide fiber) at National Aniline Division's Hopewell, Virginia plant. It is a completely self-supported structure — bubble tray column, vapor disengaging chamber, crystallizing chamber and support skirt are all assembled along the same center line.

Compact, unitized "out-of-door" construction such as this is another example of how Conkey "know-how" is helping progressive processors realize the benefits of low installation and erection costs and make maximum use of space. Optimum return for capacity, high crystal uniformity and characteristically low steam consumption provide maximum return on capital invested in Conkey systems.

Conkey crystallizers, for batch or continuous operation, are fabricated by CB&I in four strategically located, completely equipped plants. Laboratory facilities are available for pilot testing of samples. Write our nearest office for details.

LOW OPERATING COSTS AHEAD!



Conkey double effect self-supported crystallizer producing ammonium sulfate. One of several "out-of-door" systems used at National Aniline Division's Hopewell, Virginia plant.

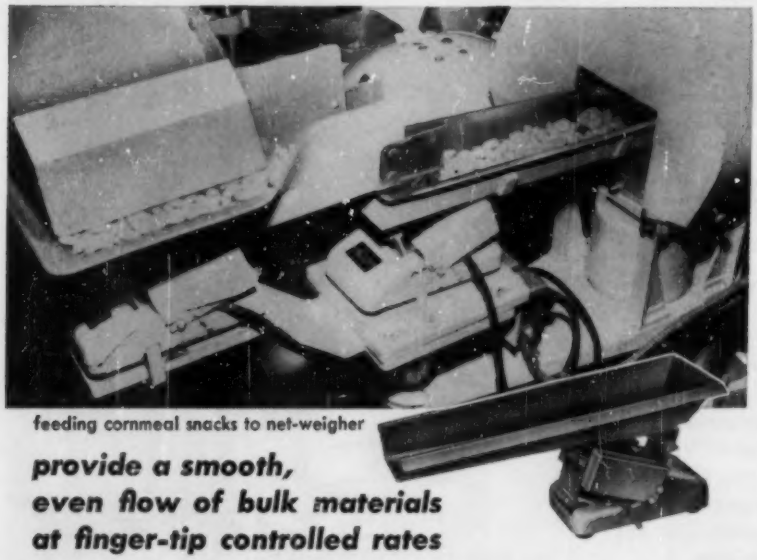
CB&I

Chicago Bridge & Iron Company

Atlanta • Birmingham • Boston • Chicago • Cleveland • Detroit • Houston • Kansas City (Mo.)
New Orleans • New York • Philadelphia • Pittsburgh • Salt Lake City
San Francisco • Seattle • South Pasadena • Tulsa
Plants in BIRMINGHAM, CHICAGO, SALT LAKE CITY, GREENVILLE, PA. and at NEW CASTLE, DELAWARE.
In Canada: HORTON STEEL WORKS LTD., TORONTO, ONTARIO

CC-33A

SYNTRON "Vibra-Flow"
VIBRATORY FEEDERS



feeding cornmeal snacks to net-weigher

provide a smooth, even flow of bulk materials at finger-tip controlled rates

SYNTRON "Vibra-Flow" Vibratory Feeders fill the gap between storage and processing. They provide a smooth, even flow of bulk materials—hot or cold, dry or damp, from powders to chunks—to mixers, batchers, driers and other processing equipment. And, the flow rate is instantly adjustable, from minimum to maximum to meet production schedule changes.

There is a type and model SYNTRON Feeder for each of your problems or needs. The variety of sizes and styles range from Light Tonnage Feeders with capacities from one to ten tons per hour to Heavy Tonnage Feeders with capacities up to hundreds of tons per hour, with flat pan, tubular and many other types of troughs. Available with electromagnetic, hydraulic or pneumatic drives.

Investigate the production possibilities with SYNTRON Vibratory Feeders in your operation. Send us the details of your problem—our application engineers will be glad to submit recommendations. CH258

Products of Proven Dependable Quality

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designed to increase production, cut production costs

Vibrators (bins, hoppers, chutes)	Rectifiers (Silicon and Selenium)
Vibratory Feeders	a-c to d-c Selenium Rectifier Units
Vibratory Screens	Electric Heating Panels
Shaker Conveyors	Electric Heating Elements
Vibratory Elevator Feeders	Sinuated Wires
Weigh Feeders	Shaft Seals
Packers and Jolters	Electric Hammers
Hopper Feeders	Concrete Vibrators
Lapping Machines	Paper Joggers

Our representatives will be glad to work with you in selecting the proper equipment for your operation.

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SYNTRON COMPANY
116 Lexington Avenue Homer City, Penna.

people in marketing

U. S. Industrial Chemicals Co. has appointed **William U. Funk** as polyethylene sales development engineer. Funk will be chiefly concerned with developments in the flexible packaging field.

Solvay Process Division, Allied Chemical Corp., announces appointment of **Solon D. Fisher** as assistant manager of its St. Louis sales branch. Fisher joined Solvay in 1948 as a salesman in the St. Louis branch.

Paul Logue has been named manager, market research, in the development department of Monsanto's Research and Engineering Division at St. Louis.

New manager of petrochemical sales for Lion Oil Co. is **Joe A. Keepers.** Keepers will be stationed in Houston, Texas, where he will be responsible for sales of products from the ethylene facilities at Texas City and other Lion Oil petrochemical products.

Gulf Oil has appointed **Sheldon E. Beadle, Jr.,** as sales representative in its Petrochemicals Department, and **Arnold G. Anderson** has been assigned to the Commercial Research Section of that department, succeeding Beadle.

Necrology

John R. Macmillan, 69, Union Carbide Chemicals Co. (retired). Macmillan was chairman of the Charleston Section, A.I.Ch.E., in 1945 and 1946.

Joseph L. Sturtevant, 84, treasurer and former president and chairman of the board, Sturtevant Mill Co., Dorchester, Mass.

Victor L. King, 72, former technical director, Calco Chemical Division, American Cyanamid Co.

Kenneth A. Kobe, 53, Chemical Engineering Department, University of Texas. Kobe was a specialist in submerged combustion processes and thermodynamics, and was consultant for several oil and chemical companies.

John S. Beekley, 63, administrative assistant to the general management, Du Pont, Polychemicals Department, Wilmington, Del. Beekley was chairman of the Charleston Section, A.I.Ch.E., from 1940 to 1941.

by unique narrow-span DYNALOG* Electronic Controller

Temperature difference control within ½ of 0.1°C — that's what American Cyanamid demands for process evaporators at their Organic Chemicals Plant in Bound Brook, New Jersey. Boiling-point rise must be held at 108.5°C, since even slight variations affect product quality.

A Foxboro Dynalog Recorder-Controller, with full-scale span of only 5°C, provides the close control American Cyanamid requires. Control is held continuously within 1/20th of a degree of set point — with chart records for proof.

Cyanamid's Narrow Span Controller was installed in 1955. It's been running continuously ever since, virtually unattended. The only servicing or maintenance required on the Dynalog has been re-inking and chart changing.

Get the complete story on the exclusive Dynalog Controller, with full-scale spans as narrow as 5°F — the narrowest span available to industry today! Write for Bulletin 20-10. **The Foxboro Company, 9312 Neponset Ave., Foxboro, Mass.** *Reg. U. S. Pat. Off.*

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REG. U.S. PAT. OFF.

DYNALOG ELECTRONIC INSTRUMENTS

A sell-out attendance of engineers hears A.I.Ch.E. National president George E. Holbrook "take stock" of engineer's unification.

Recession, trade secrets, new processes at N.Y. One-Day.

President Holbrook's luncheon address on "Taking Stock" [of the engineering profession's steps towards unification] was one of the highlights of New York's annual One-Day Technical Meeting, October 23, which drew more than 350 engineers from the Metropolitan area. Four symposia, ranging from *Cost Engineering* and *Legal Aspects of Trade Secrets and Patents*, to new industrial processes involving Foams and Froths, and Petroleum Chemicals, vied for the attention of the participants.

Cost engineering

The recession is over! Only 2 out of 212 economists surveyed according to the report of G. C. Smith, of F. W. Dodge Corp., believe that 1959 will not be a good year. As reasons for the recession ("which was more psychological than economic"), leading off the Cost Engineering symposium, chaired by Cecil Chilton of McGraw-Hill, Smith cited the "traumatic experiences" of (1) Sputnik, (2) Ike's stroke—which caused a wave of pessimism; therefore the depression (3) overexpansion, or plant overcapacity and (4) recession in home building due to fixed interest rates on FHA-VA loans. Smith commented that it was an unusual recession, in that there was (1) high employment (2) high prices (3) no stock market collapse and (4) that consumer spending held up.

Smith emphasized that we must control the basic reasons for inflation *not the symptoms*. Factors contributing to inflation are (1) government spending greater than tax receipts, (2) high tax rates on business which encourages corporate spending more

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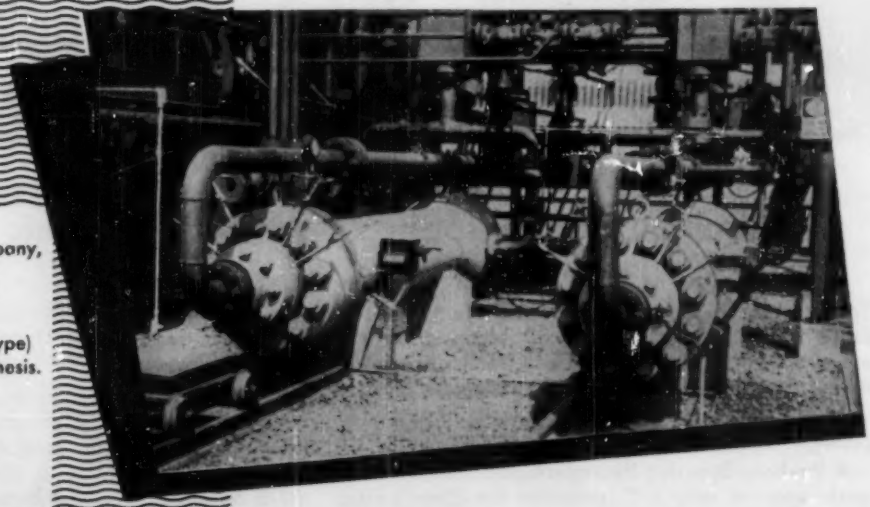
GHH H.P. Centrifugal Gas Circulators, Maulwurf-type



Spencer Chemical Company, Vicksburg, Mississippi, employs two GHH centrifugal gas circulators (Maulwurf-type) in their ammonia synthesis. These units have operated without trouble since February, 1954.

GUTEHOFFNUNGSHÜTTE
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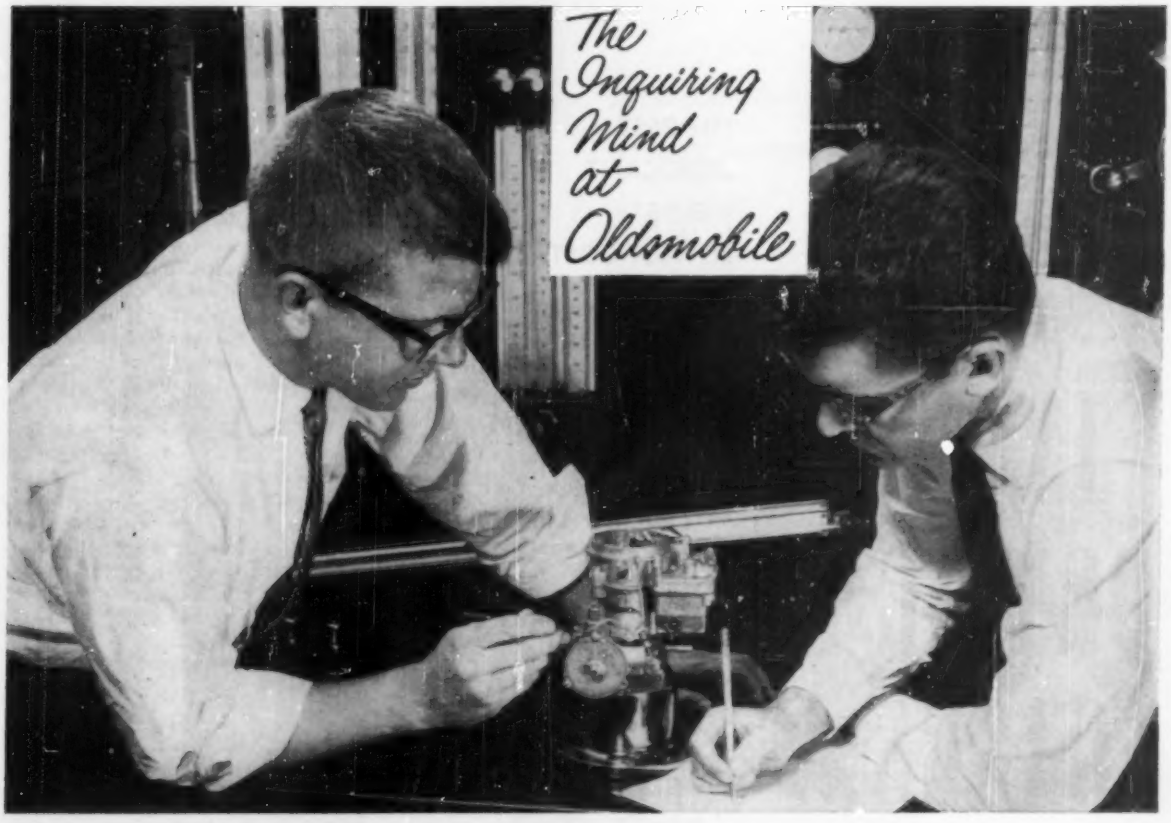


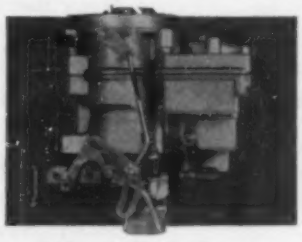
no. 6 OF A SERIES

TWO STEPS TO NEW FUEL ECONOMY

Unique Oldsmobile-developed two-stage automatic choke is a major step forward in improving automobile operating economy.

One of the important carburetor developments during the past few years was the automatic choke, a device that allows the automobile to be started in cold weather, and then keeps it running until the engine is sufficiently warmed up to sustain itself. Every automatic choke has two separate functions: 1) choking, which enriches the fuel-air mixture for starting, and 2) the idle speed control, which keeps the engine from stalling once it is started. In the past, and on all present carburetors except those used on the 1959 Oldsmobile, these two functions have operated simultaneously with the result that the engine ran on a rich mixture for the same length of time that the fast idle was "on". This resulted in excess fuel consumption.

With the introduction of the 1959 Oldsmobile, the two functions have been separated with a new and exclusive two-stage automatic choke developed by Oldsmobile engineers. An ingenious system of over-running levers allows the choke fly to open 75% sooner than previously required. The fast idle, however, remains "on" for the full warm-up period so the engine will not stall. This early elimination of the choking function represents a considerable fuel saving in cold weather when numerous short trips are made.



At Oldsmobile the Inquiring Mind is always at work, finding new and better ways to design, engineer and build finer automobiles for the most discriminating of buyers—the Oldsmobile owner. Discover the difference for yourself by visiting your local Oldsmobile Quality Dealer and taking a demonstration ride in a 1959 Oldsmobile.

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THE BEST DESICCANT YIELDS LOWEST COSTS

A drying installation is an important capital investment. Desiccant cost is a minor part of the total, yet *DESICCANT PERFORMANCE* is the measure of successful operation. Why risk your investment by use of an ordinary desiccant?

Molecular Sieves are the best desiccants. Five years of field service have proved these premium features—

- higher capacity
- lower dew point
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You can afford to *specify* Molecular Sieves. Investment may be lower, because higher capacity often permits use of smaller equipment for the job. Before placing your next order, ask your vendor to quote on a Molecular Sieve dryer.

For more information on Molecular Sieves, ask for Technical Bulletin F-1026. Write to Linde Company, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, New York.

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New York One-Day

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than usual, (3) wage escalation ("which makes inflation automatic"). Smith suggested that inflation can be controlled not by tight money, nor by wage and price control (since this tends towards socialism), but by education of the public.

It has been possible to estimate a budget and to control costs within 5% of the allowed budget, using methods worked out by L. W. Blazey and his fellow workers at Merck & Co. The nub of the system is to use standard forms (for appropriation requests, project schedules, equipment specifications, etc.); to use experienced engineers as estimators (in order-of-magnitude estimates, major ommissions are more serious than incorrect allowances); evaluate developments as they occur; and during the project to make continual comparisons of the remaining budget, versus work to be done.

At speakers pre-luncheon meeting, l. to r., Leb Kemp, John Colton, A.I.Ch.E. president Holbrook, Max Strawn.

By way of assent, C. E. Zearfoss, of Hydrocarbon Research, Inc., gave his keys to successful cost engineering, they are: *inquiry*, for what purpose is estimate to be used? *analysis of information available*, published data is poorest source, quotations are better, company records are best, *ability (i.e., experience) of the man making the estimate*, experienced men need less information to work with.

Industrial foams

"Industrial foam control is still more of an art than a science," claimed E. G. Tajkowski of G.E., getting Elmer Gaden's (Columbia U.) "Foams and Froths" symposium under way. Uncontrolled, foam can lead to economic loss and inconvenience. For example, it can cause processes to run below rated capacities, or may require over-

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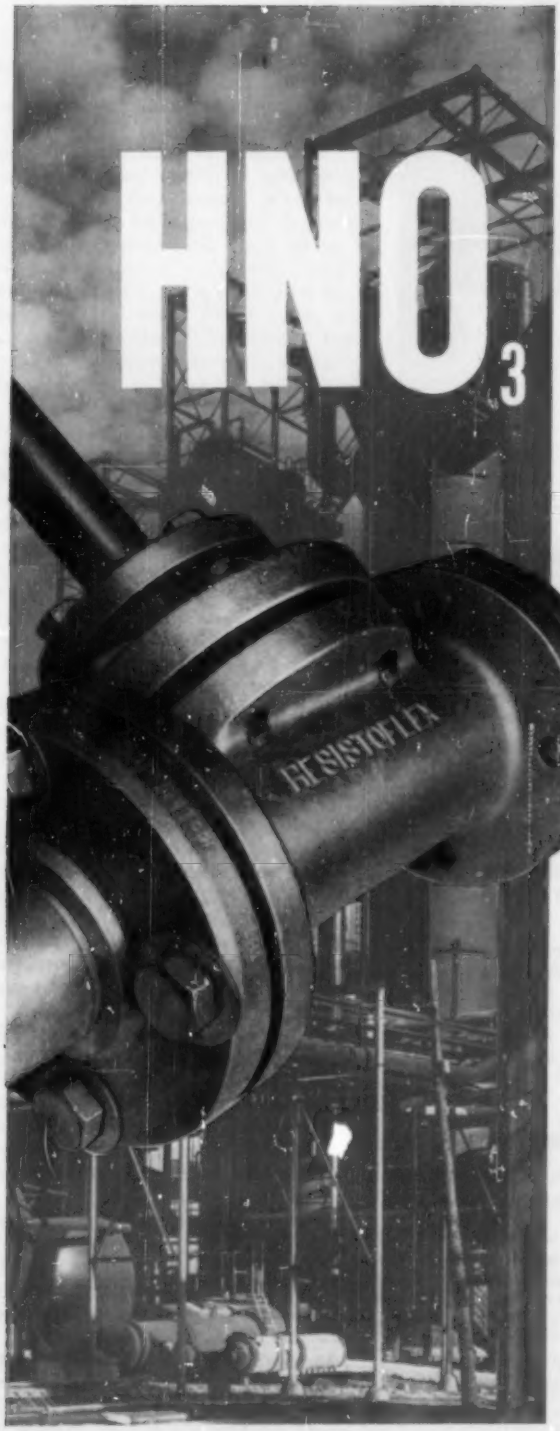

nitric acid—in any concentration, at any temperature to 500°F,

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liner of TEFLON® in thermal equilibrium with housing

Lining is completely inert to all corrosives. It's made of Fluoroflex-T, a high density, *non-porous* compound* of virgin Teflon.

Liner and housing are in thermal equilibrium through an exclusive process developed by Resistoflex. It compensates for thermal expansion differential between the Teflon and the pipe housing, eliminating fatigue collapse, and cracking at the flange.

Handling a 50% solution of boiling nitric acid at 355°F and 50 psi, Fluoroflex-T Type S piping components have been in service for almost two years with *no failures.*

Fluoroflex-T Type S piping systems can handle the toughest problems of corrosion, erosion, and contamination for you, too—with complete safety. Bulletin TS-1A gives details. Write Dept. 156, RESISTOFLEX CORPORATION, Roseland, N. J. Other Plants: Burbank, Calif., Dallas, Tex.

* *Pat. No. 2,752,637*

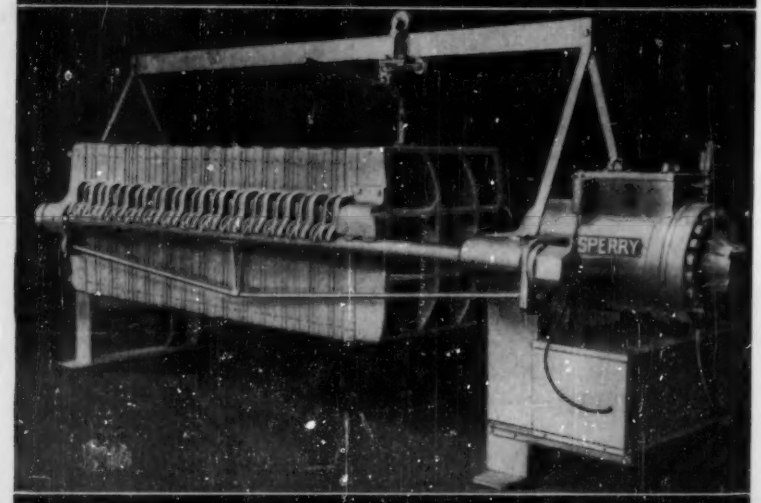
® *Fluoroflex is a Resistoflex trademark, reg., U. S. pat. off.*
® *Teflon is DuPont's trademark for TFE fluorocarbon resins*

RESISTOFLEX

Complete systems for corrosive service

LINED STEEL PIPE • FLANGED FLEXIBLE HOSE • BELLOWS • ELBOWS • TEES • REDUCERS • DIP PIPES & SPARGERS • LAMINATED PIPE

LOW DOWNTIME



with a plate and frame SPERRY FILTER PRESS

If your present filter system is inadequate to meet increased production demands . . . if excessive shutdowns, cleaning and manpower problems are dragging out your filter cycle so as to slow down your production cycle — now is the time to investigate all the advantages of a plate and frame filter press — as modernized and custom engineered to your particular application by D. R. Sperry & Company.

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Sperry Filter Presses are available in a design and capacity to handle any filterable mixture and any filter material . . . with center, side or corner feed; open or closed delivery; high or low temperature control; and your choice of labor saving devices.

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New York One-Day

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sized equipment, elaborate foam traps, or separators.

Sometimes it is necessary to precondition a system with defoamer before a process will operate according to predictions. Since there can be many differences in processes from industry to industry, or even within a given plant, it is not possible to make broad generalizations that will cover all cases. However, a scientific approach may be made to determine the optimum materials and methods to use.

"There are such things as useful foams, for instance; safety cushioning and upholstery materials," said Tajkowski, "but the most usual need is to eliminate foam." Many materials are used as foam control agents, and many ways are used to apply them. To be useful, according to Tajkowski, a defoamer material must be: 1. not soluble in the foaming system; 2. easily dispersible in the foaming system; 3. surface orienting.

Foam separation is a technique for recovering and concentrating the components of a fluid mixture, taking advantage of equilibrium concentration gradients which exist in solutions of surface-active materials. Foaming is the best method for separation of higher concentration layers from the bulk of a liquid mass. V. Kevorkian, of Esso Research, summarized the basic theory of foam separation, discussed experimentally-determined effects of operating variables, and suggested areas of application.

Outlining the results of his work in one of these areas of application, Bob Schnepf, of Columbia University, described the removal of metal ions from solution by foam separation; in particular, the removal of strontium and cesium from radioactive waste streams.

According to Schnepf, normally non-surface-active metal ions are rendered surface-active by an agent which is itself surface-active and contains sites for chelation of the metal whose removal is desired. In practice, operating variables such as gas flow rate and deliberate addition of reflux were found to be important, but for a given separation, the most important factors were found to be the chemical composition of the solution and the proper choice of foaming agent.

Petroleum chemicals

Electrostatic charges are likely to accumulate whenever granular solids,

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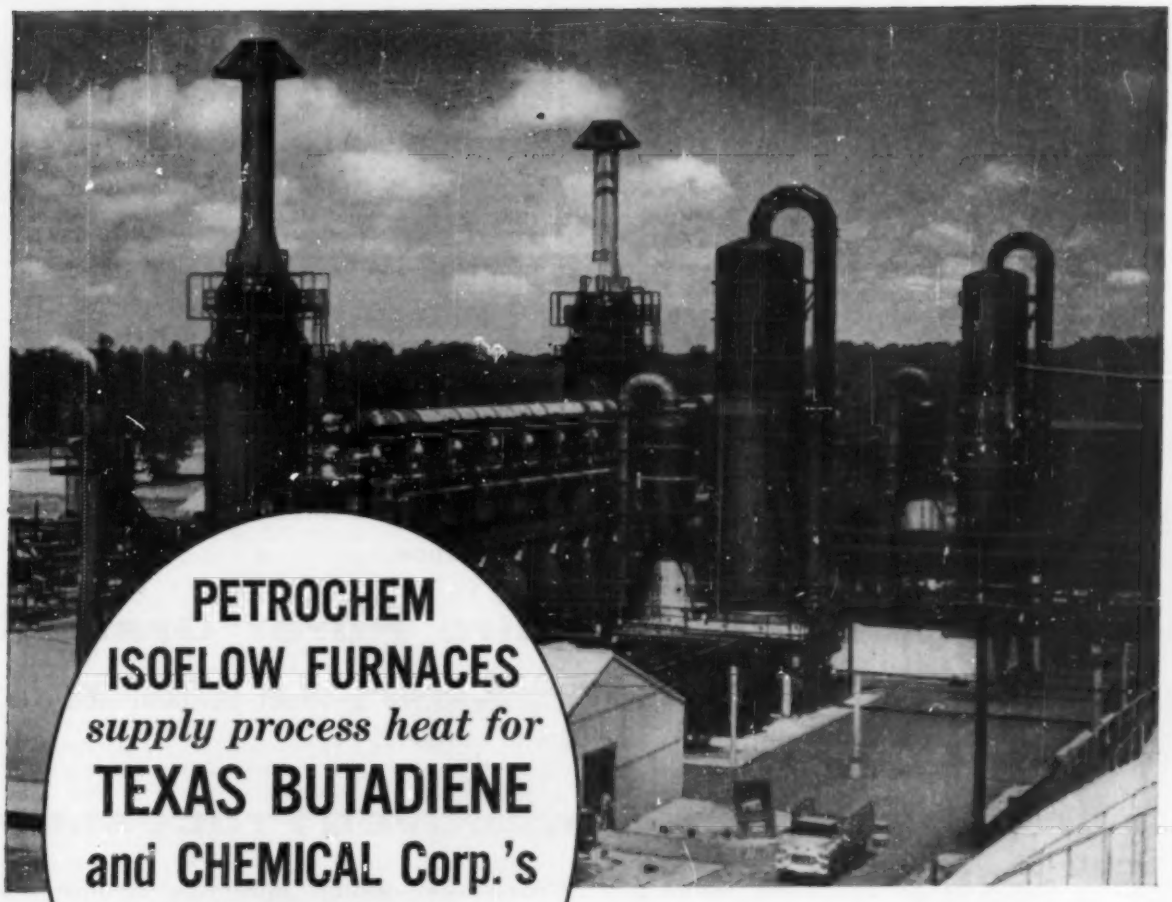

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There's a Petrochem Isoflow Furnace for any duty, temperature and efficiency.

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Purer Grades Need Improved Processes

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***New Kellogg brochure available on request**

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or nonpolar liquids are conveyed through non-grounded chutes or pipes, or when large amounts of these materials are stored in bins or tanks that are not grounded. Large-quantity storage of these materials in ungrounded bins or tanks can result in the build-up of extremely large potentials—of the order of 100,000 volts. An increasing number of fires and explosions in the petrochemical industry have fostered investigations into their cause. A correlation between flammability and explosive limits and stoichiometric mixtures of vapors, mists, or dusts, was described by D. I. Saletan of Shell Chemical Corp., during the symposium on Petroleum Chemicals, chaired by Hal Wolff of Shell, for the safe handling of potentially dangerous petroleum chemicals.

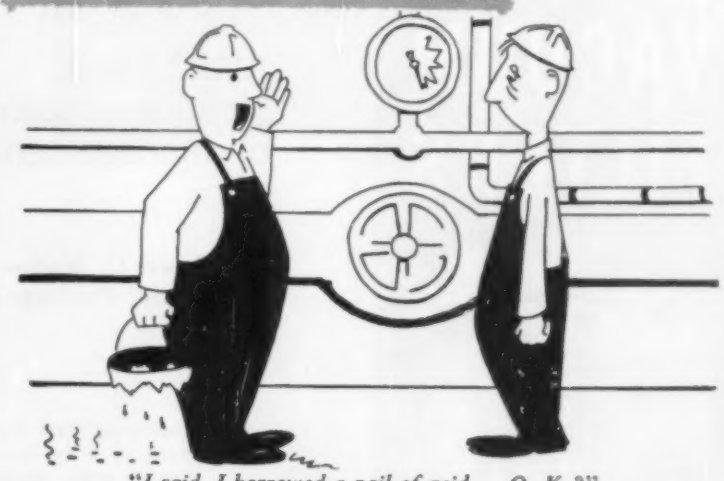
In the same symposium, John Colton, of Scientific Design, described a process developed by his associates for producing perchloroethylene in a direct one-step thermal chlorination of light hydrocarbons, using methane, ethane, or propane. To make the process workable they solved two basic problems: the removal of the heat of reaction by removal of the reaction products; and the rapid quenching of hot reactor effluent gases in cold aqueous HCl to prevent reversal of the reaction equilibrium (This particular bath provided the lowest temperature economically practical under 100°F).

Trade secrets and patents

Sparking his symposium, T. G. Gillespie, V.P. of Scientific Design, defined the U.S. patent law, and compared its leniency to foreign licensing. "To obtain a patent (with exclusive rights for 17 years) the subject matter must be new and useful, and be a process, manufacture, machine or composition of matter or improvement thereon."

"Confidential know-how," continued John Kelton, of Watson, Leavenworth, Kelton, and Taggart, "is of importance in the chemical industry. Know-how being a form of trade secret, the legal basis for protection, the problems of conflict, and penalties for threatened or actual violations are of interest." A delineation of the steps taken in the processing of an infringement suit from its inception, through trial, to final relief, occupied the interest of Myron Cohen, of Hubbell and Cohen.

Life in these excited states...



"I said, I borrowed a pail of acid... O. K.?"

High-impact, rubber-plastic, most economical for average chemicals. ½ to 6". Screw or solvent welded fittings. Valves ½ to 2". NSF-approved. *Bul. 80A.*

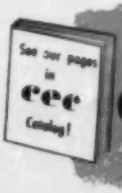
Rubber or plastic lining is economical life insurance for costly "special" equipment. It's a specialty with ACE. Write for *Bul. CE-53.*

Choice of Riviclor PVC, Ace-Ite rubber-plastic, Ace polyethylene or Ace Saran to match *any* plastic pipe. Sizes ½ to 2". Also larger plastic-lined valves.

Time Can't Be Borrowed Either

Equipment running on borrowed time due to corrosion has a knack of dropping the bottom out of production when you can least afford it. No need to risk it . . . just specify Ace chemical resistant equipment. Best for the money anywhere . . . backed by 108 years' experience.

Ace-Hide, tough as a rhinoceros, insensitive to corrosives, makes this finest of acid pails. Also dippers, bottles, funnels, etc.



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Recommendations for complete filter stations made from laboratory and pilot plant evaluations. Pilot equipment available on monthly rental basis.

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INDUSTRIAL FILTER DIVISION

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PEAPACK, NEW JERSEY

March 15-18, 1958

Atlantic City Meeting—accent on management

Lewis C. Marino
Benzol Products Co.

Chemical engineers will find themselves in the Heartland of the American chemical industry at the up-coming national meeting of A.I.Ch.E. in Atlantic City (March 15-18, 1959). New Jersey ranks first among the states of the Union in chemical manufacturing with a chemical output worth $4.3 billion in 1956, more than 30% greater than Texas, its nearest competitor (sorry). In the same year, New Jersey chemical employment was 84,220, with a payroll of $465 million, again highest for any state.

In Atlantic City itself, the earliest industry was chemical—extraction of salt from sea water by a crude evaporation process. Today, the more than 800 chemical manufacturers in New Jersey encompass every facet of the chemical, petroleum, pharmaceutical, and plastics fields. With such an em-

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The "MiniMite" Portable Potentiometer Indicator gives you laboratory accuracy in a rugged, versatile instrument. Use it conveniently for a wide range of temperature measurement, calibration and test purposes. Its dimensions are only 4" x 5" x 6"—weight is under 4 lbs. Accuracy is ¼ of 1% of scale range.

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Scale Range Individual ranges on the "MiniMite's" double-range scale are almost 24" long. Choose from 49 different range combinations to cover temperatures from −300°F. to +3200°F. for all standard thermocouples, and millivolts from −6.2 to +62.

Write For Bulletin 64-V

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barrassment of riches close at hand, a program of profitable and interesting plant trips is assured—details will follow in a later issue of CEP when the schedule has been finally set.

This will be a Resort Meeting as well. Those who might tend to shiver in advance at the thought of a seaside meeting in March are in for a mild surprise. Tempered by the nearby current of the Gulf Stream, the springtime climate of Atlantic City is many degrees warmer than that of New York. In fact, as compared to the height of the summer season, the main missing element will be the crowds. The famous Boardwalk will be clear, the sunshine warming, the shops uncrowded.

Salt water fishing enthusiasts should by all means bring their favorite gear and tackle. At meeting time, most likely candidates to be hooked by surf casting from the beach are striped bass, blackfish, and flounders. From a boat, one can reel in cod, blackfish, and pollock. (These are expected appearances only, but accurate information is posted daily). For golfers, Atlantic City is made to order; four excellent golf courses lie within a few miles of the hotel. For equestrians, horses are available for riding along the beach, a zestful contrast to the usual bridle path.

Hotel accommodation can be expected, of course, to be first rate—Atlantic City hotels are the heirs of a hundred years of inn-keeping tradition. Interesting feature of seafront hotel architecture in Atlantic City are the sundecks, from which one can look far out to sea. (It is said that, even on misty days, passing attrac-

continued on page 136

The Problem:
Protection against product contamination . . . confinement of obnoxious vapors.

G-B Supplied the answer with this INTERNALLY Jacketed Flaker

The unit shown is fitted with a G-B internally jacketed fabricated drum 60" diameter by 120" long having a polished chrome plated surface. A stainless steel steam jacketed feed pan and stainless steel vapor enclosure protect against product contamination and confine obnoxious vapors.

This is another application where G-B equipment was selected. More detailed information on request.

GB

GOSLIN-BIRMINGHAM
MANUFACTURING CO., INC.
BIRMINGHAM, ALABAMA

FILTERS • EVAPORATORS
PROCESS EQUIPMENT
CONTRACT MANUFACTURING
including HEAVY CASTINGS

Taylor Comparators combine the maximum of accuracy with ease and simplicity of operation. Colorimetric tests for pH, chlorine, phosphate, nitrate are completed in only minutes. And, you get dependable operational data to help you control crystallization, bleaching, precipitation, extraction or waste treatment. Tests are made simply by placing the treated sample in the middle test tube and moving the color standard slide across until the sample matches one of the standards. Values are then read directly from the slide. Many Taylor Comparators serve for several determinations with only a change of color standard slides.

COLOR STANDARDS GUARANTEED

All Taylor liquid color standards carry an *unlimited guarantee against fading*. Be sure to use only Taylor reagents and accessories with Taylor Comparators to assure accurate results.

SEE YOUR DEALER for Taylor sets or immediate replacement of supplies. Write direct for FREE HANDBOOK, "Modern pH and Chlorine Control". Gives theory and application of pH control. Illustrates and describes complete Taylor line.

W. A. TAYLOR AND CO.
417 STEVENSON LANE • BALTIMORE 4, MD

Atlantic City Meeting

from page 135

tions on the Boardwalk itself are sufficient to keep one's attention). All major hotels are naturally equipped with swimming pools, excellent restaurants, and dance floors.

For good food, Atlantic City need bow to no other American town—restaurant cuisine ranges from American to Continental, from Near Eastern to Oriental. If any restaurants can be singled out from among so many, they would perhaps be Hackney's and Captain Starn's.

Technical program

To get back to the main business of the day. A major accent in the technical program will be on various aspects of management. There will be sessions on Business and Technology, Market Research and the Chemical Engineer, and, finally, The Care and Feeding of Executives. Looking forward into the Space Age, other symposia will deal with such topics as Thermal Stability of Jet and Rocket Fuels, Process Data and Design Methods for Nuclear Fuel Reactors, and Missiles, Rockets, and Satellites.

Individual sessions of special interest are those on Wood as a Chemical Raw Material, and Plastic Materials of Construction. To round out the program in the fundamentals area will be sessions on Thermodynamics of Phase Equilibrium, Mechanism of Fluid Particle Systems, and Liquid-Liquid Extraction; in the field of practical engineering: Laboratory and Pilot Plant Techniques, and Start-up of a New Chemical Plant.

The symposium on Computer Control of Process Units is worthy of particular mention. This is a subject which no practicing chemical engineer can afford to neglect.

This Self-Contained Fluid Cooling System

... gives most accurate temperature control

Applied in cooling industrial machines or processes to temperatures approaching the ambient wet-bulb, the NIAGARA *Aero* HEAT EXCHANGER is independent of any more than a nominal water supply or disposal. The coolant system is a closed one, free from dirt and maintenance troubles.

Heat is removed from your process *at the rate of input*, giving you precisely the temperature you require and assuring the quality of your product. Heat may be added to prevent freezing in winter or for better control in a warm-up period. Liquids or gases are cooled with equal effectiveness.

Heat is rejected outdoors. Only the little water evaporated on the cooling coils in the air stream, or discharged to prevent hardness build-up, is consumed.

Niagara sectional construction saves you much installation and upkeep expense, gives full access to all interior parts and piping. Your equipment always gives you full capacity and "new plant" efficiency.

Write for Niagara Bulletin No. 132 for complete information

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Dept. EP-12, 405 Lexington Ave., New York 17, N.Y.
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U.S.I. CHEMICAL NEWS

Dec. ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1958

Sodium Reduction Process Yields High-Purity Zirconium and Titanium

Outstandingly pure zirconium and titanium metals are being produced by means of a U.S.I.-developed sodium reduction process at the new Ashtabula plant of Mallory-Sharon Metals Corp.

Eighty per cent of the usual impurities in zirconium do not show up in spectrographic analysis of the sodium-reduced metal. Measurements of Brinnell Hardness Number, another indication of purity, show that the sodium-reduced zirconium has a value as low as 90-95, compared with about 70 for crystal bar zirconium — the industry's purity standard — and about 130 to 150 for metal produced by the magnesium reduction process.

The sodium reduction process has the additional advantage of low cost. Zirconium can be produced by this method for less than any other means. The process for crystal bar zirconium is too expensive to make the material competitive. The magnesium process costs

MORE

"Impossible" Alloys Now Made by Bombardment

In laboratory work sponsored by the Air Research and Development Command, normally incompatible metals are being combined by a new, high-temperature, high-speed bombardment technique. Microscopic particles of one metal are propelled by a "solid linear accelerator" to speeds of over 50,000 mph, and inserted into the crystalline lattice structure of the other metal.

Researchers believe that this new technique can be used to give materials new properties or to combine the desired properties of several materials. Aluminum alloyed with iridium particles to give it better high-temperature characteristics is cited as one example.

U.S.I. Products, Plants Detailed in New Brochure

The chemical industry can now get a complete picture of U.S.I. activities through a new company brochure available on request. This 40-page, full-color booklet covers:

- U.S.I. growth over the past eight years
- plans for the future
- affiliations with other companies
- products and where they are used
- type, number and location of plants
- research facilities
- sales service facilities

For your copy of "National Distillers and Chemical Corporation Expands in the Chemical Industry," address the U.S.I. Advertising Department on your company letterhead.

Chemical Makers Complete First Year of Continuous Promotion Of the Industry to the Public

Chemical Industry Activity Committees of MCA Report Growing Progress on Local Level, Both in Participation by Chemical Companies, and in Response by the Community.

In January the Chemical Process Industries will begin the second year of a continuous cooperative public relations effort sponsored by the Manufacturing Chemists Assn. and carried out through local Chemical Industry Activity Committees (CIAC). This first year has been one of organization and idea-testing, combined with a gradual building up of local activity.

The program is now in operation in at least 380 communities and areas in 45 states. About 900 individuals in 150 companies are now equipped to work closely with local educational institutions, the press, radio and TV, community groups, organizations and clubs to acquaint the American public with the importance of chemistry in daily life.

The continuing program has been a natural outgrowth of the four Chemical Progress Week efforts. To quote General Hull, president of MCA: "Active . . . committees in a number of areas, believing that their community relations problems . . . were year-round and that they had an effective organization, have established continuing committees and have proposed that MCA sponsor a national program . . ."

Objectives of the Program

MCA feels that greater public understanding of the benefits of chemistry will also benefit the chemical industry. By building a good reputation for the CPI, MCA hopes to create a community climate of welcome for chemical enterprise, to achieve rapid acceptance of new products, and to attract top talent and more capital to the industry.

MORE

Samples of educational aids supplied by MCA.

New Synthetic Rubber Made with Deuterium

Claimed more rubbery than rubber itself, a new experimental compound — cis,1,4-polyisoprene in which all hydrogen has been replaced with deuterium (heavy hydrogen) — is being studied for explanations of the elasticity and other properties of ordinary rubber.

The new deuterio rubber seems to be more elastic, apparently because the molecules containing deuterium atoms have less attraction for each other than molecules containing hydrogen. It is naturally heavier due to the presence of heavy hydrogen. It does not need carbon black for high tensile strength.

Studies of its behavior may explain, among other things, why rubber gives up and takes up heat during deformation and recovery, and may throw some light on the infrared absorption and crystallization of rubber.

Polyethylene Membranes Extend Polarographic Analysis to Gases

It is now possible to analyze gases by polarography, without dissolving them in a liquid, by introducing a semipermeable membrane between gas and electrode. The membrane substitutes for the liquid both as a diffusion layer and as an electrical contact. Polarographic current is directly proportional to the partial pressure of the gas.

Studies so far show that polyethylene is the best membrane material. Consequently, a cell consisting of a platinum working electrode, polyethylene membrane, and a salt bridge to a saturated calomel reference electrode, has been used in most of the research work to date. The cell will analyze oxygen or sulfur dioxide in concentrations from 100% down to 50 ppm, and should be suitable for continuous analysis and control of process streams, among other applications.

Other advantages of the polyethylene membrane: it prevents fouling of electrode surfaces; it is impermeable to ions and so eliminates interferences by reducible ions in the sample.

Dec. ★ **U.S.I. CHEMICAL NEWS** ★ 1958

CONTINUED

Chemical Promotion

What the Program Consists of

Well supplied with ideas and materials by MCA, the local committees have been exploring all possible avenues of communication.

Speakers Bureaus have been set up to contact local religious, educational, social, civic, business and other groups who would be interested in chemistry as it relates to their working and living experiences. These bureaus arrange for speakers and engagements, and supply material as needed.

Press Relations have been established with all newspapers to keep them informed on local happenings and general trends in the CPI.

Radio and Television people interested in material or personalities of local significance have been contacted. Resulting programs have included interviews, panel shows on local issues, broadcasts of special events, and educational and public service films.

Community Participation by the CPI in such events as fund drives, county fairs, chamber of commerce activities and civic improvement committees has been encouraged.

Direct Mail of MCA's Chemical News and other appropriate information to "opinion leaders" in the community has been undertaken.

Educational Activities have been voluminous. MCA has prepared comprehensive material to aid teachers and students. Industry-education meetings are held widely. Special workshops and seminars, essay contests, awards, scholarships and fellowships, study programs, guest lecturers, and so on and so on, have been set up.

More companies are joining in the second-year effort as direct benefits in terms of industry-community good-will become apparent.

More information is available from MCA Chemical Industry Activity Committees, 1625 Eye St. N.W., Washington 6, D.C.

CONTINUED

Sodium Reduction

more to operate also and the zirconium does not have the purity advantage.

Sodium-reduced titanium is making an impressive showing too. All of the first month's production at Ashtabula was blended and shipped as specification metal.

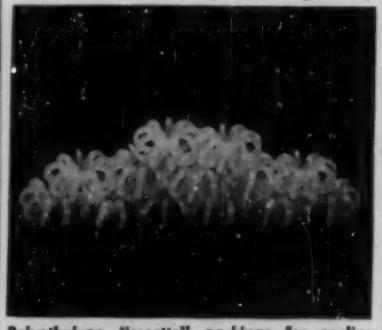
The purity achieved by sodium reduction can be attributed to several factors. The sodium, shipped from U.S.I.'s Ashtabula plant, is kept clean under argon blanketing. Brittleness is minimized in the resulting metals because oxygen and nitrogen are kept out.

Low-melting sodium can be handled as a liquid and therefore filtered and stored in the absence of air. As a liquid, it can be accurately pumped, metered and controlled. It does not alloy with zirconium or titanium.

Polyethylene "Rosettes" Ideal as Tower Packing

The Army Corps of Engineers has found that helically-wound polyethylene strip formed into toroidal "rosettes" makes a lightweight, sturdy, highly efficient packing for cooling towers. These polyethylene "rosettes" give 20-40% greater cooling efficiency at a pressure drop only 35% that of conventional packings of equivalent size. In addition, they are corrosion-resistant—unaffected by water and highly corrosive chemicals.

Used by the Army in a trailer-mounted water cooling tower — part of a mobile carbon dioxide generating plant — the polyethylene packings not only resist completely the shock of rough riding, but also cut down on the weight which must be transported. They weigh 10 lb./cu. ft. By comparison, fragile ceramic Rashig rings and Berl saddles of equivalent size weigh 48 and 45 lb./cu. ft. respectively.



Polyethylene "rosette" packings for cooling towers (photo courtesy Harshaw Chemical Co.).

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

Stannic sulfide, a gold-colored powder with talc-like consistency, is now offered in pilot quantities. Suggested for use in varnishes and lacquers to gild and bronze wood, metal, paper. **No. 1420**

Polyethylene bottles with rotating sleeve to protect label are now on market. Horizontal channels for sleeve are molded around bottle. Label is inserted through vertical opening in sleeve, is held by channel, protected by sleeve. **No. 1421**

Natural vegetable hydrocolloid now available as coagulant aid, filter, selective ore flocculant is claimed nontoxic and edible, safe for use in settling drinking water, clearing waste water before return to earth or streams. **No. 1422**

Nuclear reactor experiments are described in new book now being sold. Prepared by staff of Argonne Nat'l. Labs., volume outlines problems of design, construction, operation of reactors; gives details of equipment and experiments. **No. ..23**

New aqueous base dispersant for uncured liquid epoxy and polyester resins is being marketed. Is solvent-free, noninflammable. Said to facilitate removal of residual resins from molds and equipment. **No. 1424**

Dry chemical fire extinguisher now available is claimed to deliver a 15- to 20-foot stream of fire-killing, heat-absorbing powder over a 60° arc. Powder is nontoxic, will not freeze, corrode or conduct electricity. **No. 1425**

New caulking compound, claimed both thermosetting and thermoplastic, is based on co-vulcanization of new synthetic elastomer with asphaltic compound. Said to be permanently flexible from -30 to 165°F. Adheres to all surfaces. **No. 1426**

New bench model infrared spectrophotometer has KBr prism, permits chemical analysis in the 12.5-25 micron region. Yields more complete quantitative and qualitative information on structure of compounds such as aromatic HCs. **No. 1427**

Water-thinned contact cement for plastic luminating and other rapid assembly work is now available. Contains no flammable solvents and is claimed completely safe. Said to produce instant, strong, creep-resistant bonds. **No. 1428**

Disposable polyethylene syringe for applying adhesives, potting compounds, etc. can now be obtained. Said to deliver exact quantities of fluid without flooding, starving or dripping. Capacity about 10 cc. of fluid. **No. 1429**

PRODUCTS OF U.S.I.

Alcohols: Ethyl (pure and all denatured formulas); Proprietary Denatured Alcohol Solvents SOLOX®, FILMEX®, ANSOL® M, ANSOL PR.

Organic Solvents and Intermediates: Normal Butyl Alcohol, Amyl Alcohol, Fusel Oil, Ethyl Acetate, Normal Butyl Acetate, Diethyl Carbonate, DIATOL®, Diethyl Oxalate, Ethyl Ether, Acetone, Acetoacetanilide, Acetoacet-Ortho-Chloranilide, Acetoacet-Ortho-Toluidide, Ethyl Acetoacetate, Ethyl Benzoylacetate, Ethyl Chloroformate, Ethylene, Ethyl Sodium Oxalacetate, Sodium Ethylate, ISOSEBACIC® Acid, Sebacic Acid, Urethan U.S.P. (Ethyl Carbamate), Riboflavin U.S.P., Pelargonic Acid, 2-Ethyl Heptanoic Acid.

Pharmaceutical Products: DL-Methionine, N-Acetyl-DL-Methionine, Urethan USP, Riboflavin USP, Intermediates.

Heavy Chemicals: Anhydrous Ammonia, Ammonium Nitrate, Nitric Acid, Nitrogen Fertilizer Solutions, Phosphatic Fertilizer Solution, Sulfuric Acid, Caustic Soda, Chlorine, Metallic Sodium, Sodium Peroxide, Sodium Sulfite, Sodium Sulfate.

PETROTHENE® Polyethylene Resins

Animal Feed Products: Antibiotic Feed Supplements, BHT Products (Antioxidant), Calcium Pantothenate, Choline Chloride, CURBAY B-G®, Special Liquid CURBAY, VACATONE®, Menadione (Vitamin K_3), DL-Methionine, MOREA® Premix, Niacin USP, Riboflavin Products, Special Mixes, U.S.I. Formadry, Vitamin B_{12} Feed Supplements, Vitamin D_3, Vitamin E Products, Vitamin E and BHT Products.

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from page 133

Polyethylene featured at Local Sections

"Polyethylene may well be the first billion dollar a year plastic produced by the U. S. chemical industry," according to N. R. Smith of Bakelite (Union Carbide) at the October meeting of the **Philadelphia-Wilmington Section** *(B. A. Rausch)*. Although only some 15-20% of the industry's linear polyethylene capacity is in use at the present time, at the rate additional markets are developing capacity operation might soon be reached. Most of the polyethylene produced, said Smith, is used for flexible packaging. Cuts in price of the plastic will certainly open far wider markets, probably by 1962. Polypropylene, Smith predicted, could very possibly cut into the polyethylene market since there are certain areas where it might fill product requirements better.

Increased population in the late 1960's will mean increased per capita use of energy for space heating-cooling, transportation, generation of electricity, and industrial applications will result in a 50% increase in energy requirement by 1968, according to J. G. Winger, Petroleum Economist for Chase Manhattan Bank. At **Cleveland Section's** October meeting *(J. H. Perkins)*, Winger predicted that hydroelectric power, coal, and oil production will not grow fast enough to meet the 64-quadrillion Btu per year demand in 1968; consequently, natural gas (less lucrative to petroleum producers than oil is) will get a bigger slice of the energy pie.

Also meeting

Nashville Section *(L. D. Moore)* in October took a trip to the world's largest glass plant under one roof, the Ford Motor Company's Nashville plant. . . . **Coastal Bend Section** (Texas) *(J. R. McKlveen)* also took a plant trip in Monterrey, Neuvo Leon, Mexico, seeing a steel mill, a brewery, and a caustic plant. . . . **East Tennessee Section** *(J. C. Umberger)* heard E. M. Schoenborn, North Carolina State College, give a review of the A.I.Ch.E. sponsored research on "Tray Efficiencies for Distillation Columns" at North Carolina State at its October meeting. . . . **North Jersey Section** *(E. O. Nurmi)* recently sponsored a fall lecture series on Molecular Separations held at Newark

continued on page 152

Contamination-free Compression—all types of gases:

CORBLIN Diaphragm Type Compressors

Now exclusively distributed in the U.S.A. by the American Instrument Co., Inc.

- Outstanding Features: Absolutely no contact between gas and hydraulic fluid; gases are compressed between hydraulically-pulsed diaphragms.
- Compressors lend themselves to easy automatic operation when control is by pressure switch.
- Units can apply additional compression to gas taken directly from commercial bottles.
- Units operate efficiently with fluctuating input pressure, without need for pressure reducers or expansion vessels.
- Pressures available to 15,000 psi.—capacities to 60 s.c.f.m.

Complete information in Bulletin 4071-S *furnished upon request*

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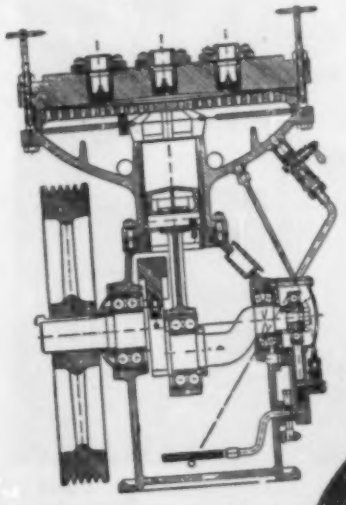
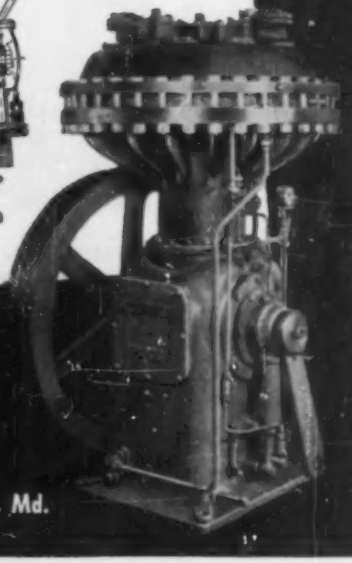
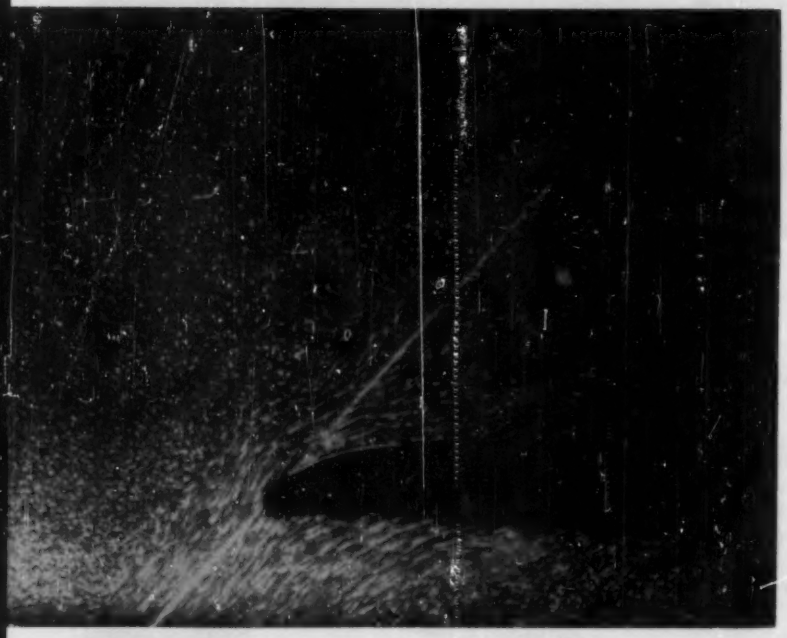


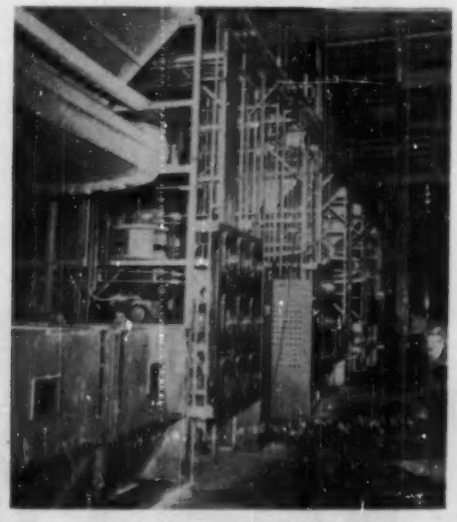


AMERICAN INSTRUMENT CO., INC.
8030 Georgia Ave., Silver Spring, Md.



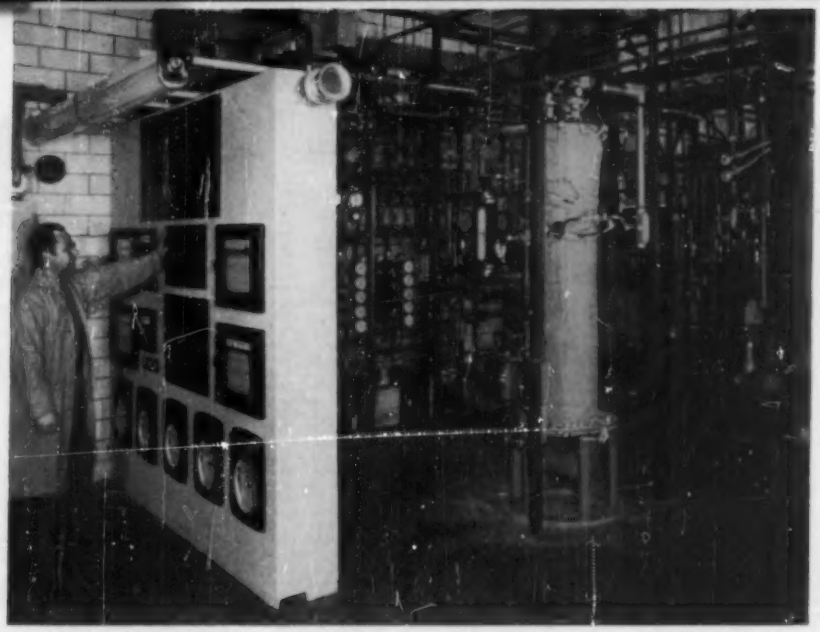
Patterns of fluid flow like this one are made visible for study in a new water tunnel at Westinghouse Research Labs. The tunnel allows engineers to study and photograph fluid flow. A stroboscopic flash unit is used to photograph the flow. Tiny air bubbles, oil droplets, or small particles of plastic are injected into the water stream to make the flow pattern visible. In this picture, air bubbles have been used to show the flow pattern.

A magnetic device the size of a pin promises to increase the "thinking" speed of future electronic computers 10 to 20 times. D. A. Meier, who directed development of the magnetically coated glass rod, for National Cash Register's Electronic Division, here conducts a memory cycle test with a completed rod assembly.

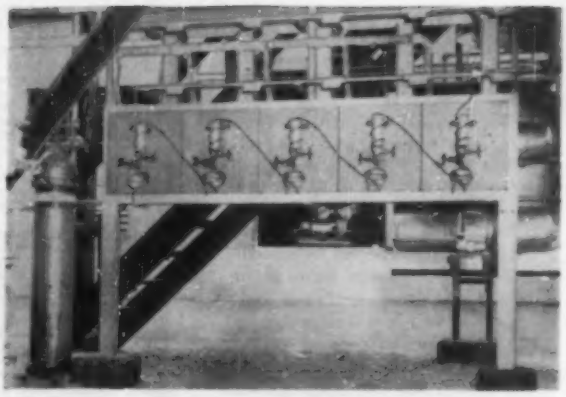


Installation of these four gas-fired, 3-pass synthetic rubber dryers has completed the extensive expansion program at Goodyear's Houston Synthetic Rubber plant. Dryers were erected by C. G. Sargent's Sons Corp.

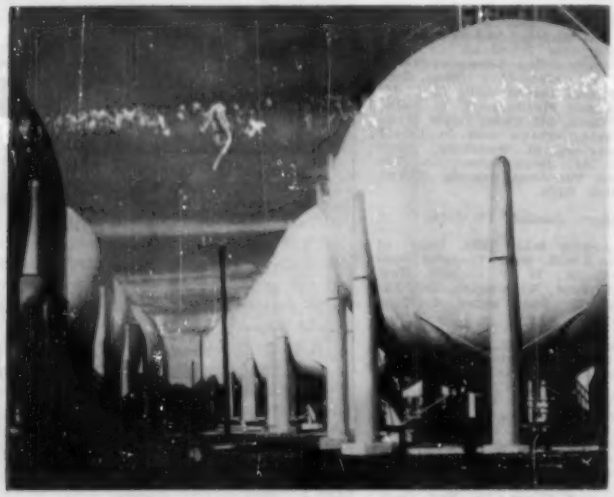
Field tests by American Agricultural Chemical Co., indicate that bronze lubricated plug valves are the answer to the corrosion problems involved in handling molten phosphorous. Bronze Rockwell-Nordstrom lubricated plug valves handled about 37,500 tons of molten phosphorous at a temperature of 76° to 84°C.



This fully-automatic pilot plant has been gathering new knowledge without human guidance since June, 1957, at the research labs of Standard Oil (Indiana). Designed for studying the behavoir of catalysts used to speed chemical reactions in refining petroleum, the pilot plant runs automatically, once a day an engineer takes readings.



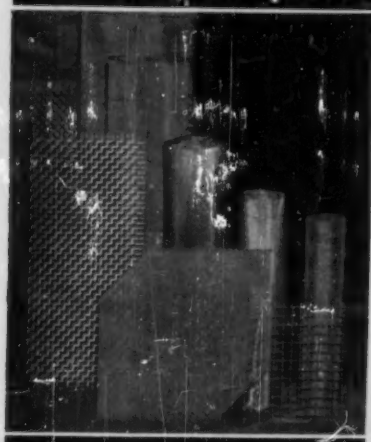
Continuous measurement of residual methane in product streams of an ammonia plant, and a specially developed sampling system that enables the use of this process instrumentation, give efficient control for the Selma, Mo., plant of Mississippi River Fuel Corp. Designed and built by Mine Safety Appliances Co., the special system uses M-S-A LIRA Infra-Red Analyzers.



Fire protection for these tanks at Texas Butadiene's Channelview plant was accomplished by spraying a special vermiculite cement material to the tank legs. It was applied by Gunite Concrete and Construction Co., Kansas City.

A motor that operates while red-hot (nearly 1000°F.) has been developed and is here tested by Westinghouse Electric Corp.

from a small piece



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1959—MEETINGS—A.I.Ch.E.

● Atlantic City, N. J. March 15-18, 1959. **A.I.Ch.E. National Meeting.** Chalfonte Haddon Hall Hotel. Gen. Chmn.: J. D. Stett, Dept. Mech. Eng., Rutgers Univ., New Brunswick, N. J. Tech. Prog. Chmn.: N. Merash, Natl. Lead Co., P.O. Box 58, So. Amboy, N. J. **Recent Advances in Plastic Materials of Construction**—M. P. Gigliotti, Monsanto Chem. Co., Plastics Div., Springfield, Mass. **Business & Technology**—J. Happel, NYU. **Theoretical and Laboratory Work on Liquid-Liquid Extraction**—R. E. Treybal, NYU, Univ. Heights 53, N. Y. **Laboratory and Pilot Plant Techniques**—G. W. Blum, Goodyear Tire & Rubber Co., Akron, Ohio. **Missiles, Rockets & Satellites**—G. C. Szego, Gen. Elect., Aircraft & Gas Turbine Div., Cinn. 15, Ohio. **General Papers** (2 sessions). J. Joffe, Newark Coll. of Eng., 367 High St., Newark 2, N. J. and E. C. Johnson, Dept. of Chem. Eng., Princeton U., Princeton, N. J. **Computer Control of Processing Units**—J. M. Mozley, Johns Hopkins Hospital, Baltimore 5, Md. **Startup of New Chemical Plants**—M. L. Nadler, DuPont, Penns Grove, N. J. **Care and Feeding of Executives**—J. S. Wilson, Heidrick & Struggles, 20 No. Wacker Dr., Chicago 16, Ill. **Mechanics of Fluid-Particle Systems**—S. K. Friedlander, Johns Hopkins Univ., Balt., Md. **Process Data & Design Methods for Nuclear Fuel Recovery**—C. E. Stevenson, Rsch. Dir., P.O. Box 1259, Idaho Falls, Idaho. **Thermodynamics of Phase Equilibria**—E. H. Amick, Jr., Chem. Eng. Dept., Columbia U., New York 27, N. Y. **Market Research & the Chemical Engineer**—William Copulsky and R. Cziner, Grace R&D Co., Hanover Sq., New York 4, N. Y. **Thermal Stability of Jet and Rocket Fuels**—C. J. Marsel, NYU, Univ. Heights, New York, N. Y. **Wood as a Chemical Raw Material**—E. G. Locke, U. S. Forest Prod. Lab., Madison, Wis.

● Cleveland, O. April 5-10, 1959. **Nuclear Congress. Co-sponsored by A.I.Ch.E. and others.** A.I.Ch.E. representative: E. B. Gunyou, Alco Prods., Inc., Schenectady 5, N. Y.

● Kansas City, Missouri, May 17-20, 1959. Hotel Muehlebach. **A.I.Ch.E. National Meeting.** Gen. Chmn.: F. C. Fowler, Consulting Chem. Engr., 7515 Troost Ave., Kansas City, Mo. Tech. Prog. Chmn.: Fred Kurata, Chem. Eng. Dept., Univ. of Kansas, Lawrence, Kansas. **Reaction Kinetics**—M. M. Gilkeson, Dept. of Chem. Eng., Tulane Univ., New Orleans, La. **Petrochemicals**—C. E. Montes, Nat'l. Petrochemical Corp., Tuscola, Ill. **International Licensing and Collaboration**—R. Landau, Scientific Design Co., 2 Park Ave., New York, N. Y. **General Papers** (2 sessions). J. O. Maloney, Univ. of Kansas, Lawrence, Kan. and Merk Hobson, Univ. of Nebraska, Lincoln, Nebr. **Non-Equilibrium Fluid Mechanics**—M. J. Rzasa, Cities Services Res. Lab., P.O. Box 402, Cranbury, N. J. **Role of Wetting and Capillarity in Fluid Displacement Processes**—C. S. Kuhn, Magnolia Petroleum Co., 907 Thomasson Dr., Dallas, Tex. **Thermodynamics of Jet & Rocket Propulsion**—G. C. Szego, Gen. Elect. Aircraft & Gas Turbine Div., Cinn. 15, Ohio. **Computers and Pipelines**—R. L. McIntire, The Datics Corp., 600 Camp Bowie Blvd., Fort Worth, Texas. **What's New in Liquid Metals Technology**—H. M. Rodekohr, Ethyl Corp., P.O. Box 341, Baton Rouge, La. **Ten Ways to Improve Technical Reports**—Robert Gunning, Blacklick, Ohio.

Deadline for papers: January 17, 1959.

Storrs, Conn. August 9-12, 1959. Univ. of Conn. **A.I.Ch.E.-A.S.M.E. Heat Transfer Conference.** Prog. Chmn.: M. T. Cichelli, Eng. Research Lab., DuPont, Wilmington, Del. Abstracts by Jan. 15, final paper deadline, March 15, 1959.

● St. Paul, Minn., Sept. 27-30, 1959. Hotel St. Paul. **A.I.Ch.E. National Meeting.** Gen. Chmn.: W. M. Podas, Asst. Rsch. Dir., Economics Lab., Guardian Bldg., St. Paul, Minn. Tech. Prog. Chmn.: A. J. Madden, Jr., Univ. of Minn. **Mixing**—J. Y. Oldshue, Mixing Equip. Co., Inc. P.O. Box 1370, Rochester 3, N. Y. **Size Reduction**—E. L. Piret, Chem. Eng. Dept., Univ. of Minnesota, Minneapolis 14, Minn. **Plastic Construction Materials**—B. M. Landis, Gen. Elect. Co., Cleveland 12, O. **Physical Properties of Liquids**—S. E. Isakoff, Dupont Co., Eng. Dept., Expr. Sta., Wilmington, Del. **Molecular Engineering**—M. Boudart, Princeton U., Chem. Eng. Lab., Princeton, N. J. **Chemical Economics as a Unit Process**—M. H. Baker, 1645 Hennepin Ave., Minneapolis 3, Minn. **More**

continued on page 144

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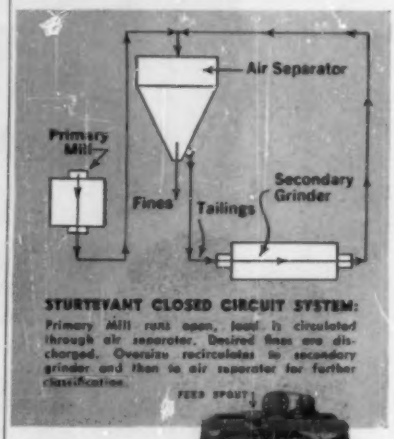

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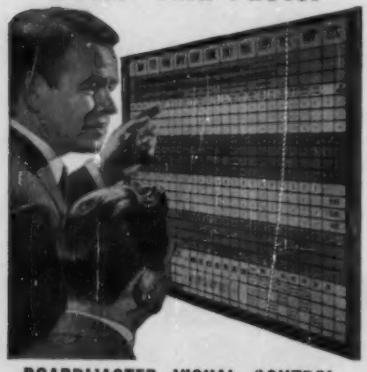

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from page 142

Research for Your Dollars—J. S. Mertes, Sun Oil Co., 1608 Walnut St., Philadelphia 3, Pa. **Process Control**—I. Lefkowitz, Case Inst. of Techn., Cleveland, Ohio.

Deadline for papers: May 27, 1959.

● San Francisco, Calif., December 6-9, 1959. **A.I.Ch.E. Annual Meeting.** Gen. Chmn.: Mott Souders, Jr., Shell Development Co., 4560 Horton St., Emeryville 8, Calif. Tech. Prog. Chmn.: C. R. Wilke, Div. of Chem. Eng., Univ. of Calif., Berkeley, Calif. **Process Dynamics**—E. F. Johnson, Dept. of Chem. Eng., Princeton, U., Princeton, N. J. **Operations Research**—R. R. Hughes, Shell Dev. Co., Emeryville 8, Cal. **Progress and Problems in Jet and Rocket Combinations**—C. J. Marcal, NYU, University Heights, New York 53, N. Y. **Secondary Oil Recovery Methods**—P. H. Poettman, Ohio Oil Co., Littleton, Colo. **New Oil Sources—Shale Gilsonits, Tar Sands: Financing in the Chemical Industry; Raw Materials for the Chemical Industry; Turbulence and Turbulent Mixing; High Temperature: Thermodynamics, Reactions, Kinetics; Devices, and Materials; Electro-chemical Engineering-Process Design; Fundamental Aspects of Chmeical Engineering in the Pulp and Paper Industry.**

Deadline for papers: August 6, 1959.

1959—Non-A.I.Ch.E.

● Houston, Texas. Jan. 26-27, 1959. Univ. of Houston. Amer. Soc. for Engineering Education. **Industry Speaks Its Mind on Engineering Education.**

● New York, N. Y. Jan. 27-30, 1959. Hotel Commodore. Society of Plastics Engrs. **15th Annual Technical Conference.**

1960—MEETINGS—A.I.Ch.E.

● Atlanta, Ga. Feb. 21-24, 1960. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: Fred Bellinger, Ga. Inst. of Techn., 225 North Ave., N.W., Atlanta 13, Ga.

● Mexico City, Mexico, June 20-24, 1960. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: G. E. Montes, Nat'l Petrochemical Corp., P.O. Box 109, Tuscola, Ill.

● Tulsa, Okla., Sept. 4-7, 1960. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co., Bartlesville, Okla.

● Washington, D. C., Dec. 4-7, 1960. **A.I.Ch.E. Annual Meeting.** Tech. Prog Chmn.: D. O. Myatt, Atlantic Research Corp., Alexandria, Va.

Unscheduled Symposia

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.
The Threatened Imbalance Between Chlorine and Alkali in American Chemical Industry: Zola G. Deutsch, Deutsch & Loonam, 70 E. 45th St., New York City 17.
Computers in Optimum Design of Process Equipment: Chen-Jung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.
Financing for the Chemical Industry: Bernard Stott, First National City Bank of New York, New York, N. Y.
Chemical Engineers in Chemical Industry Management: T. P. Forbath, American Cyanamid Co., 488 Madison Ave., New York, N. Y.
Preparation of Catalytic Cracking Charge Stocks and Quality Criteria Therefor: Wheaton W. Kraft, Lummus Co., 385 Madison Ave., New York 17, N. Y.
Solar Energy Research: J. A. Duffie, Director of Solar Energy Laboratory, Univ. of Wisconsin, Madison, Wis.
Hydrometallurgy—Chemistry of Solvent Extraction: C. H. Beyer, Dept. of Chem. Eng., Univ. Mo., Columbia, Mo.
Process Dynamics as They Affect Automatic Control—D. M. Boyd, Universal Oil Prods., Des Plaines, Ill.

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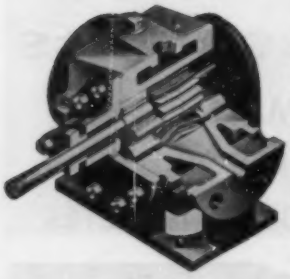

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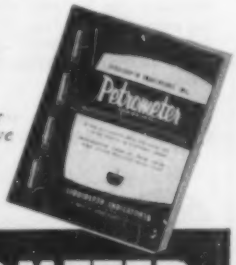

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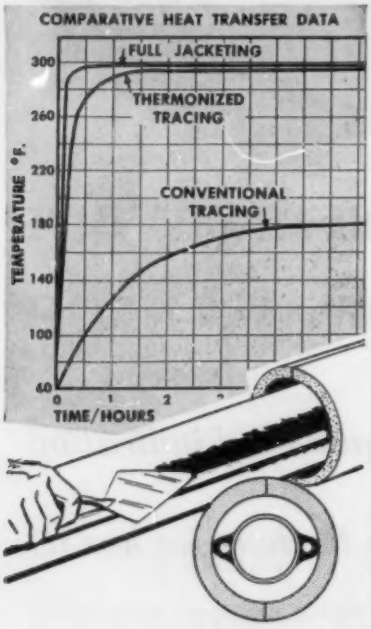

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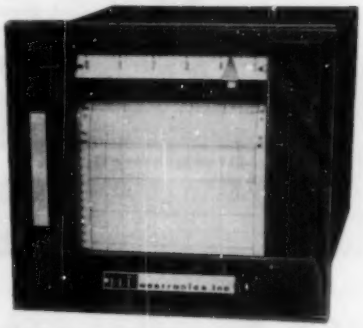

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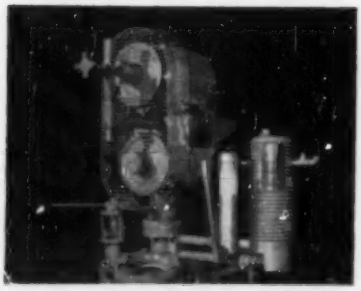

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Then we heated both to 525°F. and quenched them quickly in a 70°F. water bath. You can see what happened to #53 Glass (above, left). Glasteel 59 didn't show a sign of damage . . . in spite of a 455°F. instantaneous temperature change.

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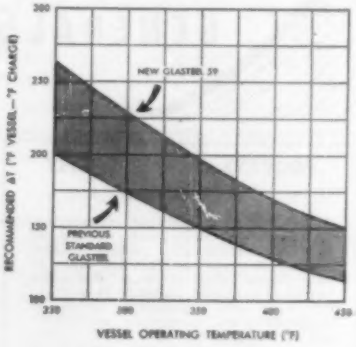

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The Situations Wanted portion of this Classified Section is preprinted and mailed a few days in advance of publication, to Employment Directors. Send names of individuals who should be on mailing list to: Miss E. Adelhardt, Chemical Engineering Progress, 25 W. 45th Street, New York 36, New York.

SITUATIONS WANTED
A.I.Ch.E. Members

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CHEMICAL ENGINEER—Age 41. Nineteen years' broad organic chemicals experience. Development, production, engineering design, etc. Proven administrative ability. Desire technical supervision or management position. Los Angeles area. Box 6-12.

CHEMICAL ENGINEER—Age 41. Desire position with responsibility in management phase of engineering. Diversified experience in process design; economic evaluation; project, development, and management engineering; production supervision. Box 7-12.

CHEMICAL ENGINEER—Eight years' research experience, also production experience, seek challenging, responsible position, preferably research supervision. Also interested process engineering economics. Experienced fluid flow, heat transfer, design of experiments, computer applications. Age 38. Ph.D., 1950. Box 8-12.

CHEMICAL ENGINEER—M.Ch.E. Age 29, family, veteran. Five years' experience in research, process development, and technical assistance. Desire challenging, permanent position with growth opportunities in progressive organization. Will relocate for permanent position. Box 9-12.

CHEMICAL ENGINEER—B.S. 1955, age 31, family. Experience in production of ethylene oxide compounds; also production supervisory experience in brown and refined sugar. Presently in South America. Desire interesting position in Latin America or Puerto Rico. Box 10-12.

CHEMICAL ENGINEER — B.S.Ch.E. 1952, M.B.A. 1958, age 30. Desire engineering or sales engineering post with oil refining company or firm related to refining. Six years' experience in process engineering and economics, have broad industry knowledge. Supervision desired. Box 11-12.

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CHEMICAL ENGINEER—B.Ch.E. Graduate credits, married, age 25. Thirteen months experience in bench scale and pilot plant development. Will relocate. Box 13-12.

CHEMICAL ENGINEER—Age 28. B.S.Ch.E., 1952. Experience in process and project engineering with high energy fuels. Desire responsible position with small firm starting or expanding its facilities. Box 14-12.

PROCESS ENGINEER—Seventeen years' experience in economic analyses, long range planning, process development, process design, and initial operation of petroleum chemical plants and oil refineries. Responsible charge of projects for engineering contractor and supervisory experience over plant engineering department for operating company. Desire position in operating company, either in engineering or production. Box 15-12.

PRODUCTION MANAGEMENT ENGINEERING—Age 40. M.Ch.E. Fifteen years' experience in chemical food processing and aerosol packaging plants. Plant manager, process engineer, process evaluation and development, production supervision. Seeking responsible position in production management. Present salary $11,000. Box 16-12.

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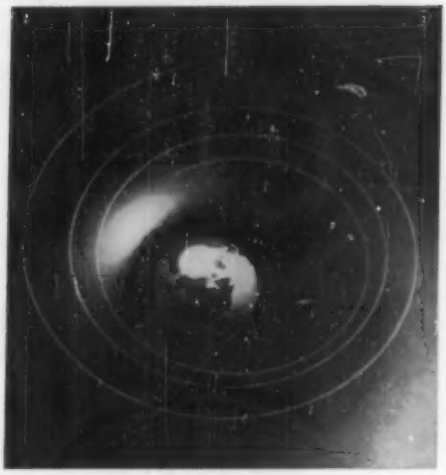
For Peaceful Purposes and the Benefit of All Mankind The National Aeronautics and Space Administration Announces its Authorization by the Congress of the United States



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(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

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SITUATIONS WANTED

A.I.Ch.E. Members

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CHEMICAL ENGINEER—M.S., married. 31. Four years' experience in process development (pilot plant), one year economic evaluation of proposed new processes, two years' process improvement. Currently a supervisor in process improvement. Desire position in process development. Box 18-12.

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CHEMICAL ENGINEER—B.Ch.E., age 30, veteran, married. Five years' experience in process development and product research in cereal products and frying fats. Good knowledge of statistical methods. New York City area. Box, 27-12.

CHEMICAL ENGINEER—M.Ch.E., age 36, family. Fourteen years' experience in petroleum, chemical and synthetic fiber industries includes research, development, pilot plant, plant assistance, economic evaluations, and consulting. Desire responsible, challenging position. Box 28-12.

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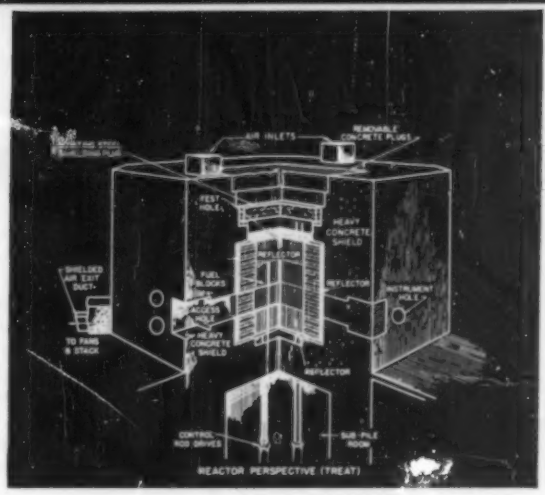

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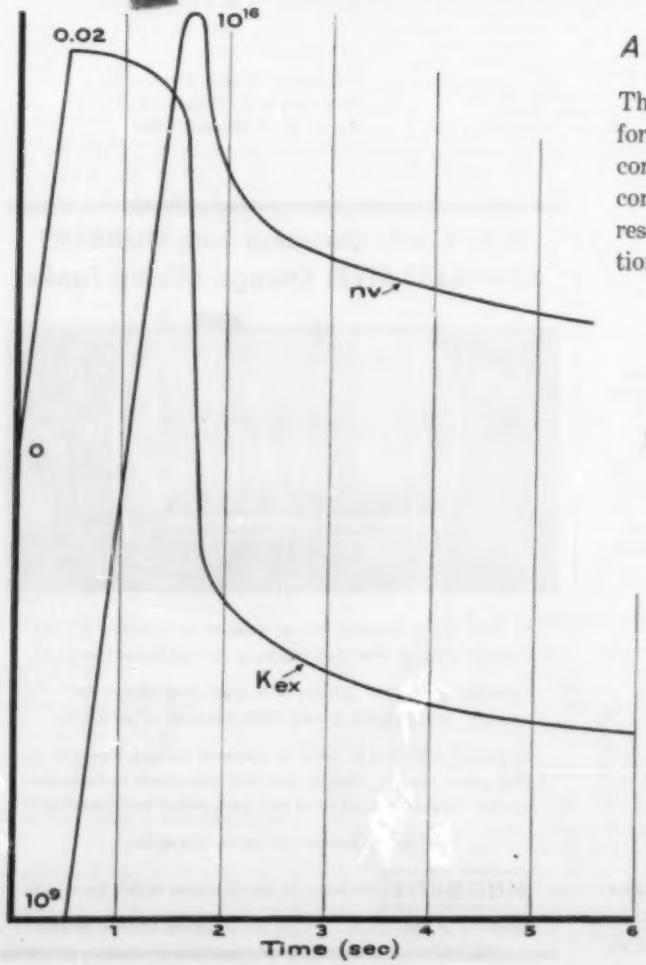

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local sections

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College of Engineering. . . . **Alton-Wood River Section** *(A. W. Frazier)* considered the problems of solid and liquid propellants for rockets at its October meeting under the leadership of speaker R. H. Cooley, Chromalloy Corp. (See page 106). . . . **Detroit Section** *(H. W. Grubb)* in November heard W. H. Mohrhoff, Parke, Davis, analyze the methods of Foreign operations in the chemical industry. . . . **National Capital Section** *(W. Watkins)* had an inside look at the Design and Operational Problems of the 707 Jet Aircraft given by C. E. Roberts, Boeing Airplane Co., at its October meeting. . . . **New Jersey Section** in October heard T. E. Heathcote, New Jersey Board of Professional Engineers and Land Surveyors, present a case for the professional licensing of chemical engineers.

A. I. Ch. E. candidates

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Narcowich, William E., *Ashland, Pa.*
Neal, Richard L., *Albany, N. Y.*
Norberg, James A., *Idaho Falls, Idaho*

Park, Donald E., *Baton Rouge, La.*
Parkin, Jerry L., *Bountiful, Utah*
Patton, William R., *Galena Park, Texas*
Perret-Gentil, Carlos, *Cheshire, England*
Peters, Donald L., *Charleston, W. Va.*

Radford, John D., *Baton Rouge, La.*
Raiford, Leslie L., *El Dorado, Ark.*
Randall, I. Eric, *Tarzana, Calif.*
Robertson, Alan D., *Camden, S. C.*
Rogers, Glenn J., *Akron, Ohio*
Ross, David, *Los Angeles, Calif.*
Roth, Donald David, *New Martinsville, W. Va.*

Salley, Jack R., *Springhill, La.*
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Sargent, Donald H., *So. Charleston, W. Va.*
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Scott, J. B., *Quebec, Canada*
Scott, Royce M., Jr., *Union, Mo.*
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Sensiba, Seth C., *Fritch, Texas*
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Showalter, E. Lee, *Richmond, Va.*
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Vige, R. Eric, *New Orleans, La.*

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Weiss, Samuel, *Morris Plains, N. J.*
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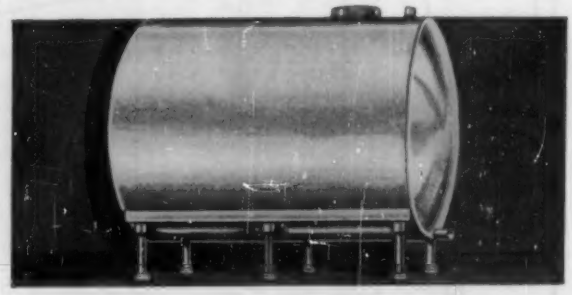

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news and notes of A.I.Ch.E.

Kenneth Kobe, graduate professor of chemical engineering at the University of Texas, died on Sunday, November 2. This is a great loss to chemical engineering and to the A.I.Ch.E. Our sympathy goes to his family and to his colleagues. Ken, as everyone who has read this column knows, was an active committee member and the author of the yearly "Chemical Engineering Faculties." The announcement of his death reached my desk at exactly the same time as copies of the most recent edition of "Chemical Engineering Faculties." In fact, Dr. Kobe's initial attack occurred in the post office just as he was mailing the copies to this office. He died in his sleep the next day. Ken was a man of great energy and accomplishments, and his many friends throughout the country will be interested to know that a memorial is being planned in his honor. Full information may be obtained from the Chemical Engineering Department of the University of Texas, Austin.

Member Gifts Campaign—A number of Local Sections have already gone over the top. Even though the campaign is still under way and A.I.Ch.E. has a good distance yet to go, enthusiasm for the United Engineering Center is apparent from the following results . . . F. Pfeiffer of Southern Nevada has reached 202% of his section's quota, C. W. Swartout of St. Louis has reached 178%; East Tennessee, under R. H. Morrison, has reported 147% of its quota. These three campaigns are essentially finished. Several sections have exceeded

their quotas before the completion of their campaigns . . . J. R. Kernan of Charleston has 106%, D. W. Anderson and W. J. Leisten of Detroit have 136%, W. S. Frank of Northeastern New York has 132%, O. F. Hardy and E. L. Boehm of Southwest Louisiana, a brand new section, have reached 127%.

A newcomer to the member-gifts drives being sponsored by all the interested societies is the American Institute of Industrial Engineers, which has a quota of $70,000.

Committee Chairmen for 1959—Admissions, R. F. Shaffer; Awards, W. B. Franklin; Career Guidance, Ray Katzen; Chemical Engineering Education Projects, M. W. Bredekamp; Constitution and By-Laws, H. F. Nolting; Education and Accreditation, C. C. Monrad; Equipment Testing Procedures, C. H. Brooks; Pollution Control Engineering, W. L. Faith; Program, H. D. Guthrie; Public Relations, T. A. Burtis; Research, Karl Hachmuth; Standards, J. C. Lawrence; Student Chapters, J. G. Knudsen; Symbols and Nomenclature, D. O. Myatt.

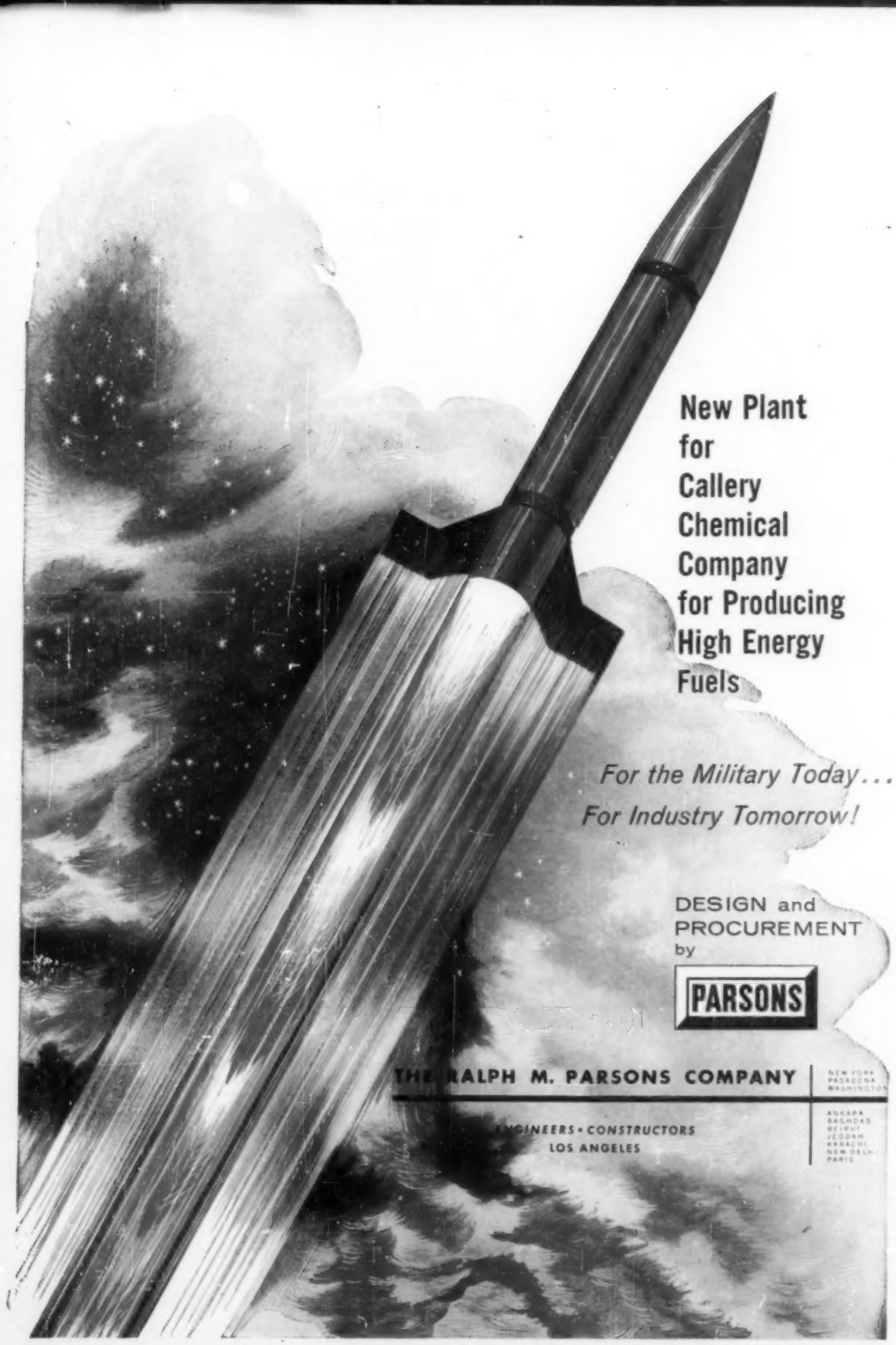
Students at Cincinnati—Once again we have news that the Procter and Gamble Company will make Student Chapter awards to eighteen schools

to enable some eighty students to attend the Annual Meeting of A.I.Ch.E. H. J. Peddicord started this program several years ago and now Bruce Martin is continuing it.

Membership—Irv Leibson's new report is on blue paper to reflect his disappointment that the Northern division under Sam West is still ahead in the number of memberships received. However, Irv has made a move that may put him ahead, for he has sent a list of nonmember chemical engineers to the Southern division membership committee.

Ichthyologists (the Local Section in Boston) have sent out a meeting notice displaying a reproduction of the Fiftieth Anniversary medallion . . . It makes an attractive presentation, turned out by Ralph Wentworth.

—F.J.V.A.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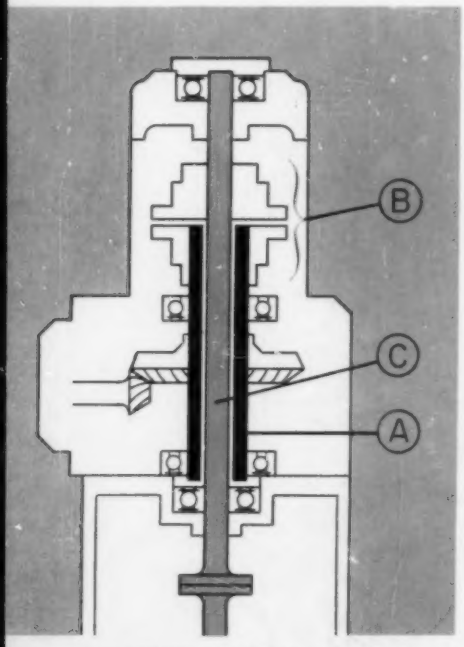

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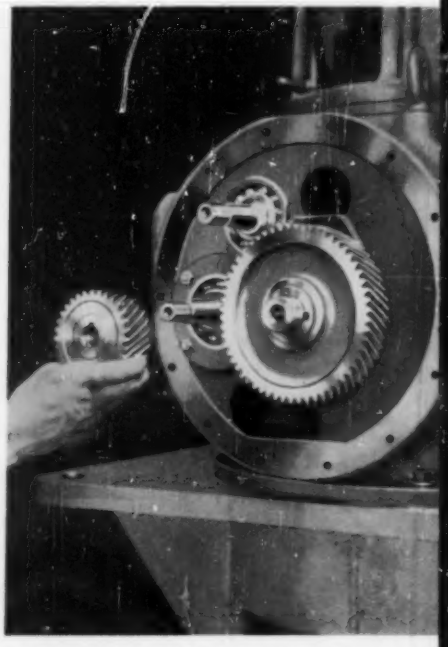

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